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MANNED ORBITAL SYSTEMS CONCEPTS STUDY

BOOK 5 - USER ANALYSIS SUPPLEMENTAL TASK

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FOREWORD

The basic MOSC study encompassed a nine-month effort which examined the requirements for, and established the definition of, a cost-effective orbital facility concept capable of extending manned operations in Earth orbit beyond those visualized for the 7- to 30-day Shuttle/Spacelab system. Following the configuration development activity in the basic study, an additional six-month effort was initiated to provide for the identification of new uses, applications and needs for the Manned Orbital Facility (MOF). This supplemental task had as its purpose a verification of the design concept and identification of suggested or desirable additions or changes to the configuration. In addition, a preliminary mission model for the MOF was developed for the 1985 to 2000 time frame.

The study effort for the basic nine-month MOSC study is reported in four books. Book 1 presents an executive summary and overview of the study, Book 2 describes the derivation of requirements for extended duration missions, Book 3 describes the configuration development, and Book 4 describes the programmatic analyses. The results and findings of the six-month supplementary study task are reported in this document (Book 5.)

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Section 1
INTRODUCTION

The preliminary definition of the free-flying manned orbital facility developed in the basic MOSC Study was based upon the analysis of potential payload requirements. The requirements were derived from NASA Mission Model planning sources, from selected sortie payloads defined in the SSPDA documentation, and from other payload data made available to the Study Team (see Book 1). The groundrules for the conduct of the study emphasized a low-cost design approach to construction and operation of the facility. The emphasis on minimizing cost suggested the use and reuse of available hardware, the employment solely of STS to deliver the necessary orbital elements, and the achievement of orbital manpower efficiency through the provision of flight periods extending past 30 days. The resultant definition of the preliminary concept was characterized by a modular, four-man, 90-day resuppliable space station which could be expanded in building-block fashion to provide additional capability as workloads and mission requirements might demand.

One of the purposes of the user analysis supplementary task described in this document (Book 5) was to examine additional use of the baseline facility and to iterate the definition of payload requirements against the preliminary baseline definition as a validation of the design concept. Along with this iteration it was believed desirable to identify additional mission requirements beyond those utilized in the original baseline Mission Model and upon which the requirements for the concept developed in the initial portion of the MOSC Study was based. This revised mission model could then provide a point of departure for the planning of near term space station activities (1985 to 1991) as well as longer range space station activities (1992 to 2000). These additional or new uses included commercial and industrial class activities in the later time periods.

The initial step in the supplemental task (see Section 2) was to contact a representive group of individuals and organizations who were concerned with future needs and payloads. The in-flight configuration of the MOF as described to the individuals contacted is shown in Figure 1-1. The payload shown attached to the free-flying manned spacecraft is representative of the assemblage of instruments and sensors necessary to support (1) atmospheric, magnetospheric, and plasma research in space (a derivative of the AMPS activity) and (2) communication technology applications in a low earth orbit (200 nmi). It was chosen as an example because it included pressurized and unpressurized sections. Figure 1-2 illustrates the modular approach that comprises the present baseline design. Figure 1-3 shows six typical views of other future operations that might be supported by MOF.

As presented to potential users, the MOF program would include three facilities, each with appropriate logistics support. One would be positioned in a low-altitude (200 nmi), 28.5 degree orbit; another would be located in a 200 nmi polar orbit, and a third would be at a geostationary equatorial location. The relative time periods when the facilities would be available

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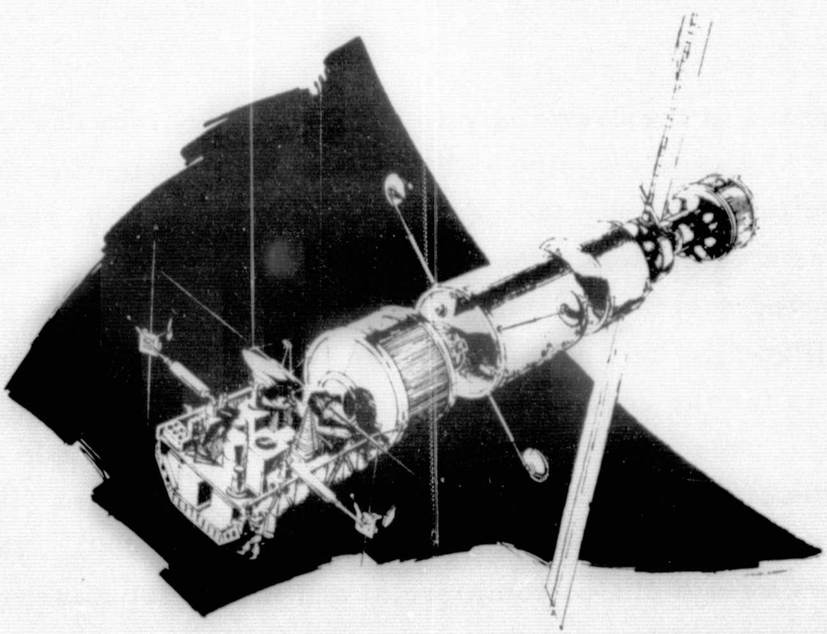

Figure 1-1. Manned Orbital Facility

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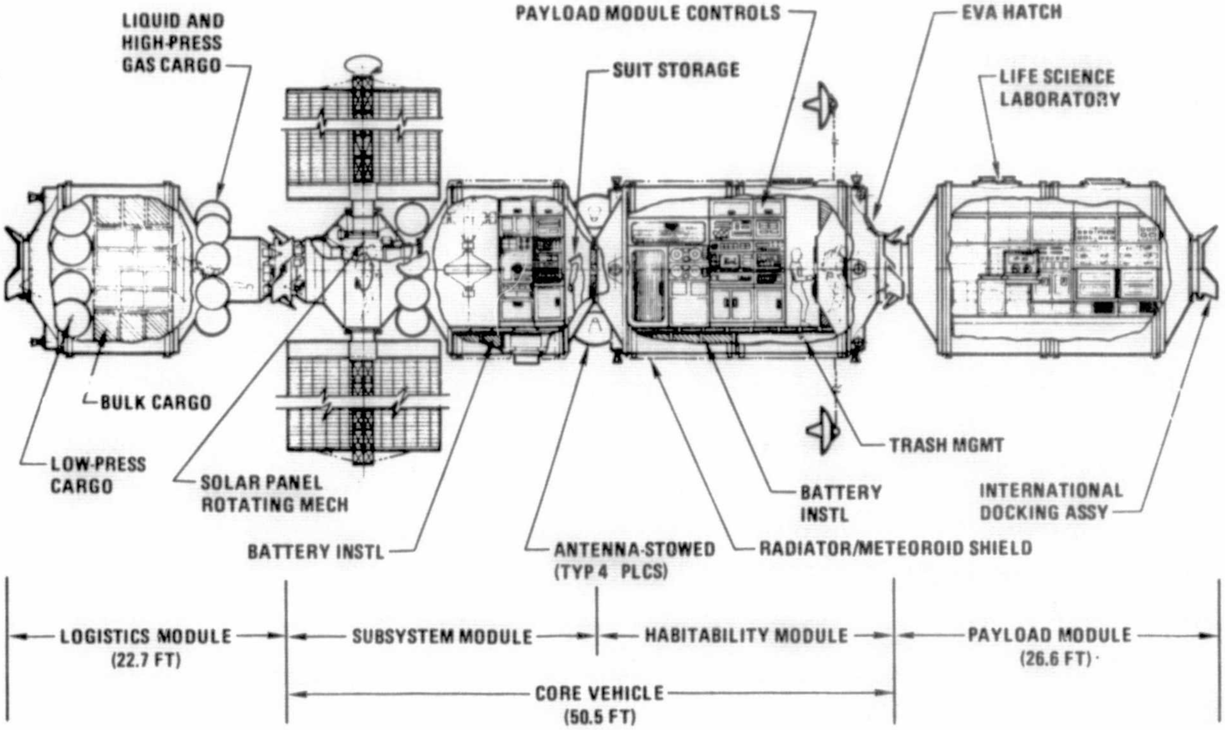

Figure 1-2. MOF 4-Man Configuration

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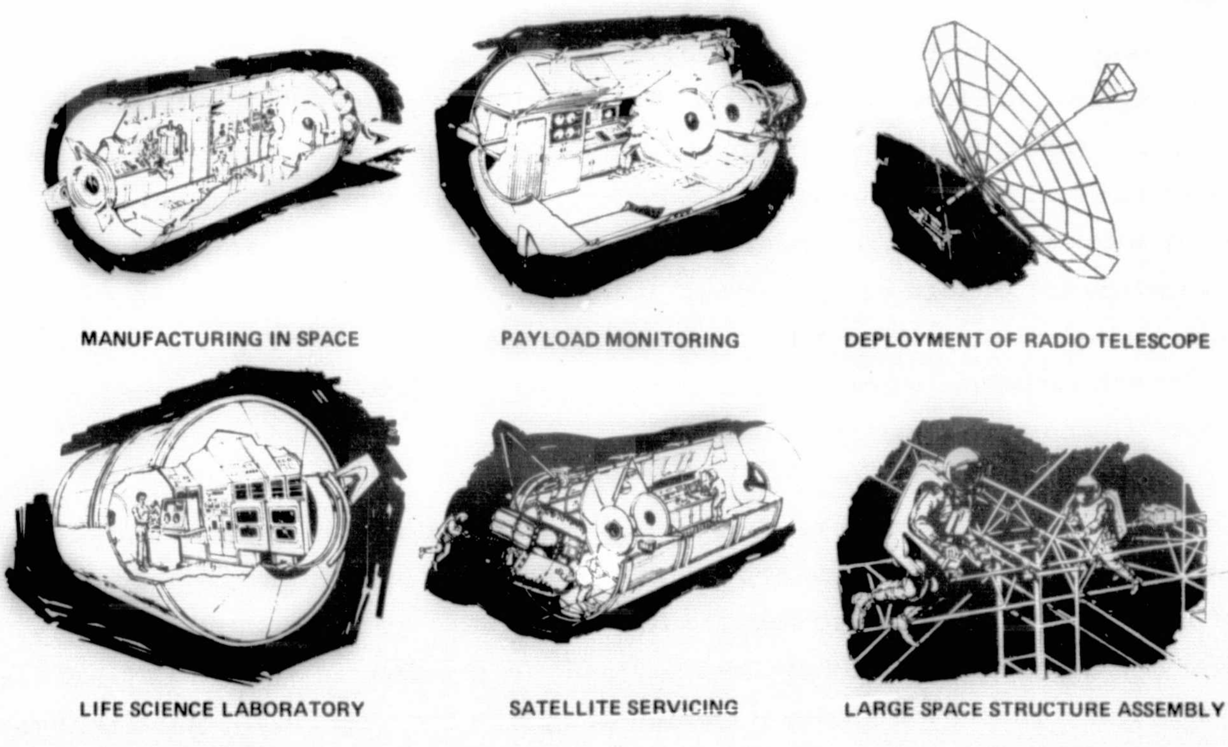

Figure 1-3. Typical Operations Supported by MOF

were defined as 1985 for the 28.5 degree orbit, 1987 for the polar orbit, and the late 1980's for the geosynchronous station. Configurational, functional, and operational characteristics were also provided to the representatives of potential user groups.

An evolutionary change in the character of payloads has been observed during the last 15 years and it can be expected that this evolutionary pattern will continue to be observed as permanent manned space station capabilities are developed. The first space payloads launched were fairly simple in design and operation. These early scientific and application satellites had to be relatively simple in order to be completely automatic in operation. As experience was gained, direct applications of the data to real-time needs could be made. For example, the first weather satellite, TIROS I, was launched successfully in 1960 and has served as a prototype of today's operational systems. With increasing applicability, however, increases in sophistication become desirable. As the level of sophistication increases, the number of subsystem elements increase; and for such a system to become operational in the automated mode, tradeoffs of reliability versus feasibility must be made.

With the advent of the Mercury program in 1963, followed by Gemini and then Apollo, the first manned experiments became possible. The first man-attended experiments that could be considered payloads were carried aboard missions in 1964. It was not until the Skylab mission in 1973, however, that truly manned payloads, wherein very complicated research protocols with flexibility for change as operational conditions warranted, became an operational reality. For the first time, during the Skylab program, space research activities were specifically designed to utilize manned command, control, and modification capabilities.

During the early Shuttle era (1980-1985) the short duration flight time will limit man's participation in orbital research activities. Many payloads will of necessity be required to operate in an automatic or semiautomatic mode. Many of the unmanned and manned payloads (e. g., Shuttle System Payload Description Activities payloads) which comprise the mission models for these early flights reflect this need for automation.

As manned facilities become available for extended periods in space, significant changes in payload conceptual design approaches will occur. As suggested in Figure 1-4, the freedom and flexibility provided by manned laboratories will be essential in the industrialization of space. During this future period the approach to payload development will have evolved to a point where the payload design will be significantly different than earlier approaches. For example, payloads for both commercial and scientific missions will become more sophisticated by taking advantage of on-orbit modification and repair. Payload updating will be undertaken where improvements resultant from advances in technology, component reliability, and enhanced performance can be accomplished. In this manner a specific payload can be kept from growing technologically obsolete with the passage of time.

Large-scale assembly operations, commercial manufacturing ventures, and on-orbit satellite servicing eventually will become feasible as the capabilities for supporting very significant manned activities as space bases are established and the true industrialization of space begun.

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PRE-SHUTTLE ERA	EARLY SHUTTLE ERA	SPACE STATION ERA
AUTOMATED PAYLOADS SCIENTIFIC APPLICATIONS OPERATIONAL WEATHER AND COMMUNICATIONS MANNED PAYLOADS ATM EREP SKYLAB MEDICAL SKYLAB COROLLARY SUITCASE	SSPDA CARRYOVERS ↕ NEW PAYLOADS CLOUD PHYSICS LIFE SCIENCE MATERIALS AND PROCESSES INTERIM SPACELAB PERIOD	COMMERCIAL AUTOMATED COMSATS, METSATS AND ERSATS AUTOMATED SCIENTIFIC MANNED APPROACH TO PAYLOADS SCIENTIFIC RESEARCH ASSEMBLY OPERATIONS SATELLITE SERVICING COMMERCIAL MANUFACTURING

Figure 1-4. Evolution of Space Station Payloads

In the following pages Section 2 describes the study approach, Section 3 presents the results of the survey of new users, Section 4 describes the rationale and development of the preliminary MOF mission model, and Section 5 presents facility design improvement recommendations and discusses operational impacts and implications. Section 6 presents the study conclusions and Section 7 presents recommendations for further activity.

Section 2
STUDY APPROACH

To satisfy the objectives and intent of the study effort the following steps were taken:

- A technical description was prepared of the functional and operational features of the Manned Orbital Facility (MOF) in terms of a preliminary baseline design.
- The description was presented to a selected group of individuals and organizations who are representation of potential future users of the MOF.
- After receipt of comments from the group, additional uses, applications and needs for the MOF were identified.
- In addition to the comments received, other sources of planning information were examined and specific high-value missions were identified.
- Using the information available a preliminary mission model was constructed covering the 1985 to 2000 time period.
- Suggestions for baseline facility design additions and/or changes were collected and documented.
- The long-term utilization potential for the MOF was described as viewed by the individuals and groups contacted during the study.

As an aid in describing the features of the MOF to be considered by the contributing new users, a document entitled, "Manned Orbital Facility: A User's Guide," was prepared at the outset of the study. The document by design emphasized the support features that could be provided by the MOF concept in accommodating a wide variety of payloads. The contents of the guide include numerous examples of payloads and space activities that are candidates for implementation during the operational manned space program of the 1985-to-1991 period and beyond. Distribution of this User's Guide was made within NASA and to the individuals and groups of individuals contacted during the course of the study.

By gathering the comments of those individuals to whom the MOF description was presented and by also examining sources of planning information, it was possible to accomplish three major objectives. First those missions which could be termed high-value or high-interest in the future were identified. It was important to identify these missions in order to determine, at least as an initial step, the critical issues to be addressed and the justification rationale for the future space systems. Secondly, a preliminary mission model was developed to provide in essence a master program for MOF from which it will be possible to develop during future study activities an assessment of the flight scheduling requirements, logistical support requirements and the payload and cargo transportation requirements for the future MOF systems. Further the mission model can be used as a "strawman". It can be reviewed, updated and modified, as required, to reflect a general agreement of the mission objectives and payload requirements by the scientific, applications, and industrial communities as well as other government agencies. A third objective achieved was (1) a validation of the design as represented by the baseline MOF and (2) an identification of design areas which should be emphasized in future trade studies and design selection and qualification activities.

2.1 SOURCES OF USER NEEDS

The 15 individuals and groups contacted by the MDAC study team are listed in Table 2-1. In addition to the industrial, commercial and institutional contacts made by MDAC, MSFC contacted the agency sources listed in Table 2-2. Comments received from the individuals contacted are contained in Appendix A.

In addition to the persons contacted, the documented results of three pertinent planning studies were examined. These studies provided further insight and identification of mission requirements over the longer term periods extending to the year 2000. These studies were (1) Commonality of Space Vehicle Applications to Future National Needs (Aerospace Corporation Contract NASW 2727), (2) Practical Applications of Space Systems (SAB-NRC Contract NSR-09-012-106), and (3) "Outlook for Space" Study, Interim Results (Hearth Committee). Section 3 of this report contains additional discussion on the use of these study findings.

Table 2-1

MDAC CONTACTS

Person	Organization	Interest
Selwyn Enzer	Center of Futures Research	Demography
Ivan Bekey	Aerospace Corporation	New space initiatives
Philomena Grodska	AIAA Technical Committee on Space Processing	Space processing
R. J. Gunkel	MDAC Representative-NASA - RTAC Space Vehicles Panel	Space vehicles
Gilbert W. Ousley	GSFC	International cooperation
Richard D. Johnson	Summary Study — ARC and various universities	Space colonization
Athelstan Spilhaus	NOAA-consultant/author	Benefits to nation and mankind
Peter E. Glaser	A. D. Little Inc.	Space Power
Kerwin, Weitz, Pogue	JSC Astronauts Office	Payload/vehicle/crew interface
T. Theodore Fujita	University of Chicago	Severe storms
Edward Kruszewski	LRC-RTAC	Large space systems/ structures
William R. Marx	MDAC-East	Space production/ electronic components
W. H. Steurer	AIAA Technical Committee on Space Processing	Space processing

A further source of useful mission planning information has also been found in the OAST Space Technology Workshop Briefing Charts dated August 15, 1975. Other sources found to be of value to mission planning efforts and of use in defining payloads and describing mission requirements are listed in the bibliography at the end of this report.

Table 2-2
MSFC CONTACTS

Person	Organization	Interest
James H. Bredt	NASA-HQ Code ES	Space Manufacturing
Rufus R. Hessberg, MD	NASA-HQ Code MM	Life Sciences
W. Ray Hook	NASA-LaRC Code 418	Advanced Technology
Edward A. Gabris	NASA-HQ Code RS	Advanced Technology
Gerald W. Sharp	NASA-HQ Code SG	Space Sciences
Dudley G. McDonnell	NASA-HQ Code EB	Applications
Ernst Stuhlinger	NASA-MSFC Code DS30	Activities in Geosynchronous Orbit
Charles A. Lundquist	NASA-MSFC Code ES01	Astronomy and AMPS[1]
Charles R. Chappell	NASA-MSFC Code ES23	AMPS

[1] Atmospheric, Magnetospheric and Plasmas Investigations in Space

2.2 ORGANIZATION OF USER NEEDS

Within the context of the MOF user analysis the results and tentative findings of the interviews and related studies were examined as sources for defining potential objectives and requirements of the space system users of the future. Before discussing these findings, it is appropriate to discuss the organizational scheme that was used to document the information gathered.

In general, as presented to the potential users, the MOF is designed to support the following classes of space activity:

A. Scientifically oriented investigations in the fields of astronomy, astrophysics, solar physics, physics and chemistry in space, life sciences, and earth sciences.

B. Technologically oriented applications in the fields of meteorology, earth observations, communications, navigation, material processing, and manufacturing in space.

C. Space-basing operations, including assembly of large structures, station buildup, construction of permanent manned facilities, and (eventually) building of space colonies.

D. Support of space operations through in-orbit spacecraft servicing, vehicle refueling, and maintenance and repair of space system elements.

E. Monitoring and control operations, including staffing of permanent manned air- and space-traffic control facilities, communication stations, and observatories.

F. Military applications and defense requirements.

Heretofore only the first two classes have been studied in some detail and the MOF baseline design was configured to accommodate 19 payloads related to these classes. The payloads utilized in the baseline study were derived primarily from the Shuttle System Payload Description Activity (SSPDA), a NASA planning effort that has defined more than 200 individual manned and automated payloads for the first 12 years of STS operation. In the User Analysis Task the goal was to supplement the first two categories (science and technology) and examine the other areas of potential utilization.

The comments and suggestions obtained from the potential new users contacted were categorized, along with the objectives and space initiatives cited in the three studies referenced in Paragraph 2.1, into seven major areas to be considered for MOF utilization. For each of the seven major areas identified, a

further breakdown by major disciplines in each area was made. These seven categories together with the discipline areas associated with each are as follows:

Major Missions	Major Activities
1. Acquisition of scientific knowledge (basic research missions)	A. Astronomy B. Solar physics C. Space sciences D. High-energy astrophysics E. Life and health sciences
2. User-oriented technological applications (applied research missions)	A. Earth resources B. Meteorology C. Materials and processes in space D. Communications
3. Education, information resources, and mass media (information services missions)	A. Student experiments B. TV demonstrations C. Point-to-point and personal communications D. Broadcasting
4. Commercial and industrial applications (commercial missions)	A. Manufacturing in space B. High vacuum operations C. Space power D. Commercial communications E. Space storage
5. Operations in space (service missions)	A. Assembly – large structures B. Satellite servicing C. Support of tug operations D. Satellite command and control
6. National and international uses of space (Government operations)	A. Enhancement of national prestige B. Support of international cooperative missions C. Deterrent to conflict
7. Defense operations	(not examined in the study)

2.3 REQUIREMENTS IDENTIFICATION APPROACH

The organizational logic portrayed in Figure 2-1 summarizes the various elements that were brought together in forming the MOF mission model. The initial time period represented in the model (1985-1991) reflects to a large extent the current planning for manned space mission as recorded in previous NASA mission models. (The NASA October 1973 Space Shuttle Traffic Model prepared by the Shuttle Utilization Planning Office was used as a starting point in the study.) The SSPDA was the primary source of payload definitions

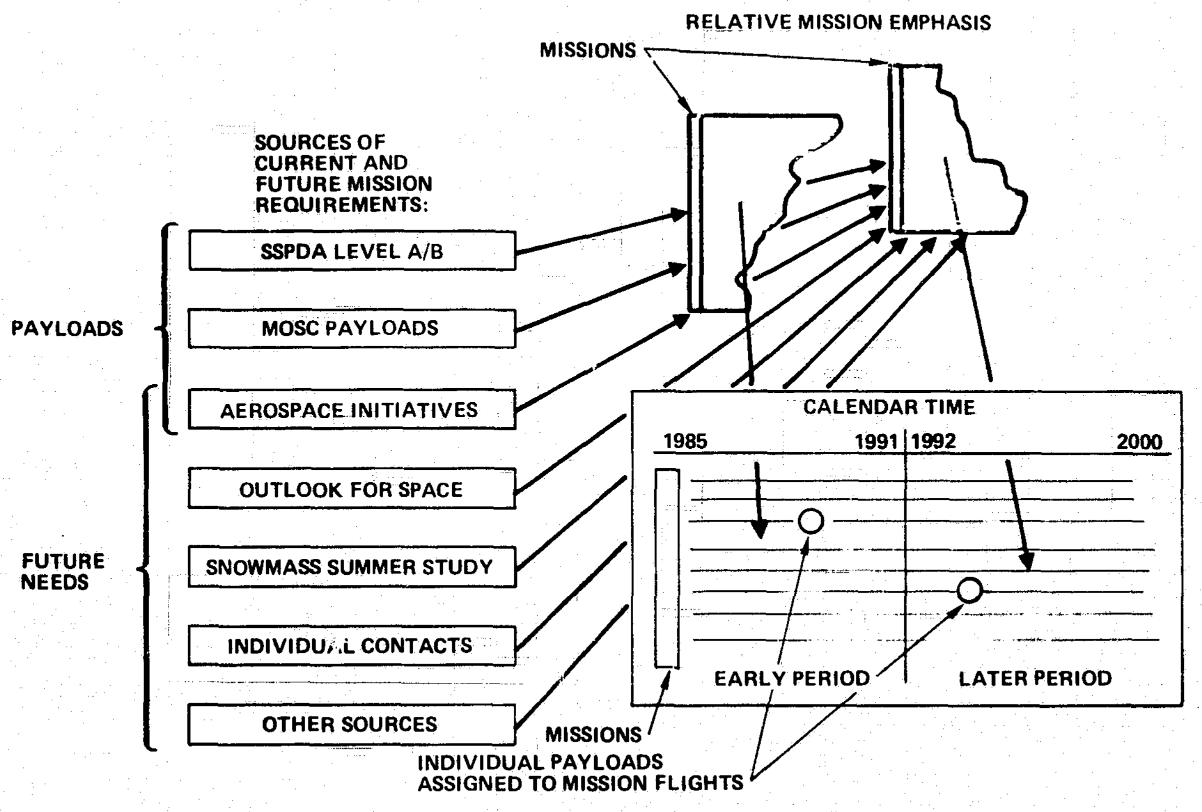


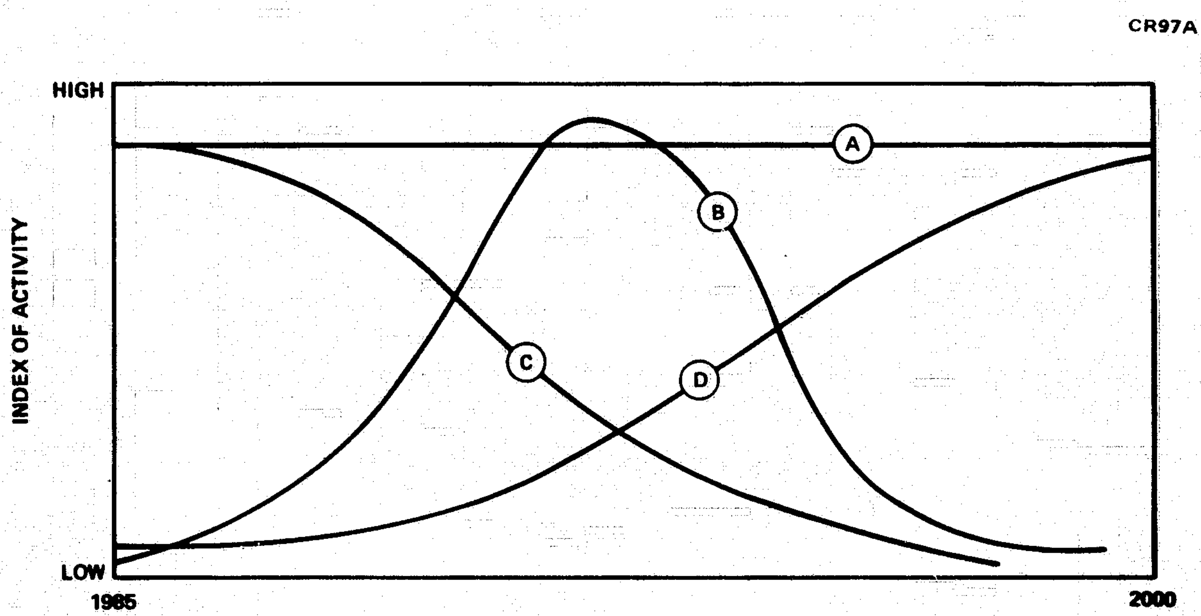
Figure 2-1. Synthesis of MOF Mission Model

for the early time period . As noted in the figure, for the later period (1992-2000), it was necessary to draw upon other sources of information in order to identify the goals and objectives of these longer term missions.

In order to identify the mission requirements for the later time period, the study had to rely on more advance sources of planning information than those available solely from the 1973 NASA mission model and the SSPDA documentation. This identification process could be characterized as a "user needs" approach. That is, by an orderly examination of the objectives for future space applications, mission requirements could be identified and also related to MOF major mission activities. The sources of future mission requirements included (1) individuals contacted during the study and (2) documented results of current and related planning studies. When a MOF user need reflecting a future mission requirement was identified, relationships were established to the standard MOF mission activities list according to the following criteria:

- Direct involvement of individual or objective with one or more MOF mission activities
- Stated interest by user in other MOF mission activities
- MOF mission activities required for a multidiscipline approach to problem solution
- Forecasted future technological advances or requirements within an identified interest area

The study examined the relative emphasis placed upon individual mission activities for both the early and the later time periods. This examination of the major mission areas provided at least qualitative insight into changes which might be expected in the near-term and far-term operational emphasis of manned missions. Figure 2-2 depicts the different emphasis patterns which can be anticipated over the 1985 to 2000 period based upon the information gathered in this study. Curve A is typical of those activities in the basic sciences which will be of continuing interest in advanced space missions.



TYPICAL MISSION ACTIVITIES:
A – ASTRONOMY, EARTH RESOURCES, COMMUNICATIONS RESEARCH, MATERIALS AND PROCESSES
B – SOLAR PHYSICS
C – SPACE SCIENCE, HE ASTROPHYSICS, TV DEMONSTRATIONS
D – SPACE MANUFACTURING, LIFE SCIENCES RESEARCH, METEOROLOGY, SATELLITE SERVICING, ASSEMBLY LARGE STRUCTURES, COMMERCIAL COMMUNICATIONS

Figure 2-2. Time Distribution of Manned Mission Emphasis

Curve B is typical of mission areas where interest changes in accordance with some cyclic requirement such as levels of solar activity, while Curves C and D represent areas of decreasing and increasing emphasis respectively. Typical of mission activities in pattern C are demonstration and prototype operations whereas space manufacturing and other commercial applications are typical of pattern D.

Section 3
RESULTS OF NEW USER CONTACTS AND LITERATURE REVIEW

The sources of new user needs encompassed as broad a coverage as was permitted by the time periods allotted to the contacts of individual experts and authorities and the available resources of the study. In addition, during the baseline MOSC study and continuing into the supplementary task, many valuable references on potential future missions were accumulated in the data available to the study team. A listing of the pertinent references utilized in this task is included at the end of this report.

In the selection of the individual user contacts, particular attention was given to interviewing those who could perhaps give an independent or fresh view of the utility and validation of the MOF design concept. Hence, the choice of individuals included members of the academic community, potential industrial users, and other agency contacts who were removed from the main stream of ongoing space system planning efforts. Also included were three of the Skylab astronauts who are considered to be the foremost authorities on the habitation and operational aspects of manned space missions such as those that could be supported by the MOF class space station.

3.1 RESULTS OF INDIVIDUAL USER CONTACTS

Specific comments received from the individuals interviewed during the course of the study are included in Appendix A. The reader may find the commentary below useful in gaining an overall perspective on how the persons contacted felt regarding the directions which future manned space program could follow.

There are six technical subject areas of commentary which merit discussion related to the direction of future manned missions. These include (1) market forecasts as related to future worldwide population trends, (2) long range weather services which can benefit mankind, (3) future possibilities in advancing space technology applications, (4) the industrialization of space operations

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as viewed by individuals knowledgeable in space processing technology, (5) the future of space colonization, and (6) selected examples of emerging requirements for scientific research conducted in a manned orbital facility in geosynchronous orbit. These six subjects are discussed below.

3.1.1 Market Forecasts Related to Population Trend

In the discussions pertaining to future populations, one of the topics that arose frequently concerned the question of the MOF users of the future. That is, what portion of mankind in the years to come can be expected to represent the true customers for the services provided in the class of space facilities offered by the MOF. Knowing the true customer will in turn help identify the critical issues to be addressed in advance space missions. The heart of this issue lies in understanding the future trends of the world population and growth.

Geographical Trends in World Population

Fundamental to an understanding of future world population levels is an appreciation of some basic demographic relationships. An excellent treatize of this subject is found in the work of Tomas Frejka(1), the noted Czechoslavakian demographer. By 1970 the population of the world had reached 3.6 billion and was growing at the rate of 2 percent per year. If this rate were to continue, the population would double every 35 years or by the year 2005; and would reach almost 15 billion in only 70 years. However, if changes were to occur in the future as characterized by lowered birth rates and death rates resulting in an overall lowered total fertility rate, the total world population would not experience this growth rate. Frejka has prepared several projections of world population based on a collection of individual projections for many separate regions of the globe. Figure 3-1 is a representation of the classification of the major geographical areas. Most of the major areas of the world consist of countries at approximately the same stage of demographic transition from high birth and death rates, although significant differences in the rates of each area are observed. Some areas such as Europe, North America, and the USSR are economically developed and are characterized by birth rates of around 18 live births per thousand inhabitants annually, and death rates of about 10 per thousand. Other areas classified as

(1) The Future of Population Growth-Alternate Paths to Equilibrium, Tomas Frejka, John Wiley and Sons, New York, 1973.

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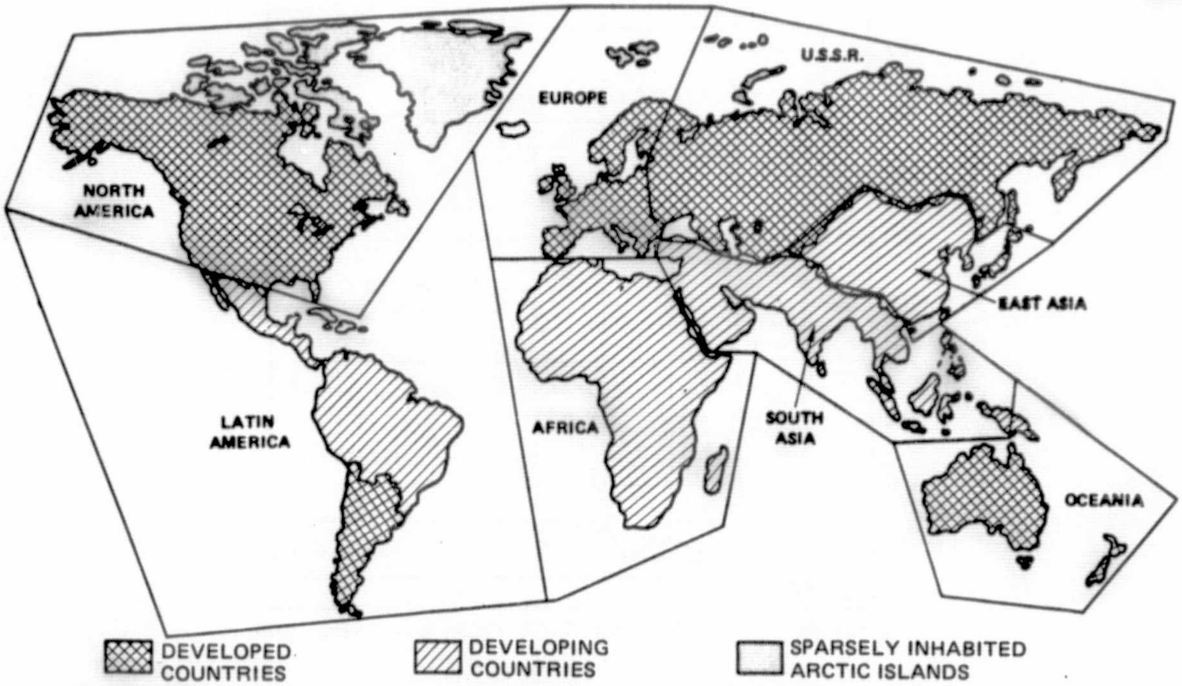

SOURCE: POPULATION BULLETIN, WORLD POPULATION PROJECTIONS: ALTERNATE PATHS TO ZERO GROWTH, VOL 29, NO. 5, PP6, POPULATION REFERENCE BUREAU, INC., WASHINGTON, D.C., 1974.

Figure 3-1. Demographic Classification of World Regions

economically emerging nations display higher birth rates of over 40 and death rates about 15. Thus the average population growth rate for developed countries is only about 0.9 percent per year while that of the less developed countries is probably 2.6 percent per year.

Since the less developed countries contain over two-thirds of the world population, these differences are quite important. Frejka's population growth projections for the developed and less developed regions are shown in Figures 3-2 and 3-3, respectively. The three curves on each chart represent three values of the complex demographic statistic[(2)] net reproduction rate (NRR). The NRR refers to the number of girls born per woman who could survive to childbearing age, assuming particular levels of fertility and mortality. An NRR of 1.0 always corresponds to fertility at the replacement level. While the details of the demographic statistics and calculations are beyond the scope of this report, it is sufficient to say that an

(2) Population Bulletin, World Population Projections: Alternate Paths to Zero Growth, Vol 29, No. 5, pp 4-5, Population Reference Bureau Inc., Washington D.C., 1974.

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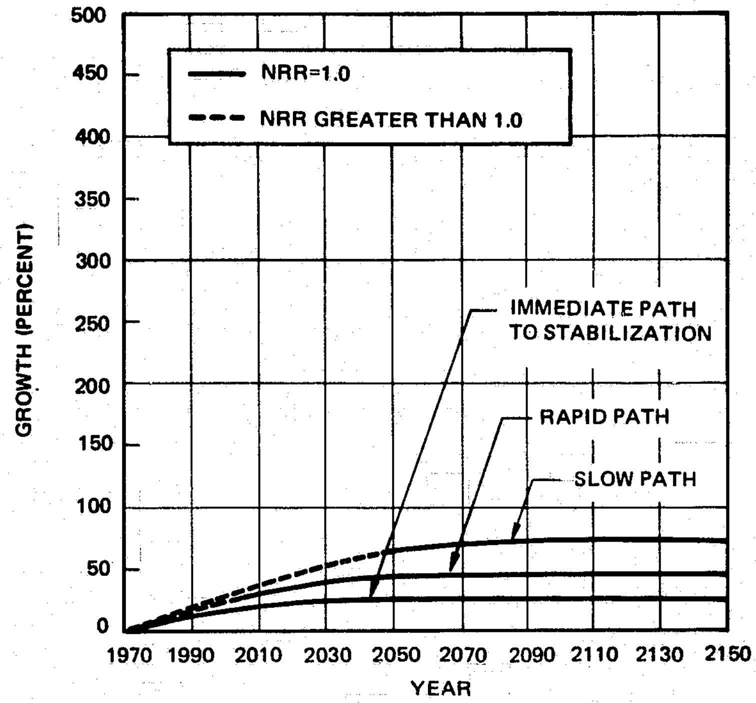

SOURCE: THE FUTURE OF POPULATION GROWTH - ALTERNATIVE PATHS TO EQUILIBRIUM, TOMAS FREJKA, WILEY, NEW YORK, 1973

Figure 3-2. Population Growth Potential of the Developed Regions, Selected Paths, 1970–2150

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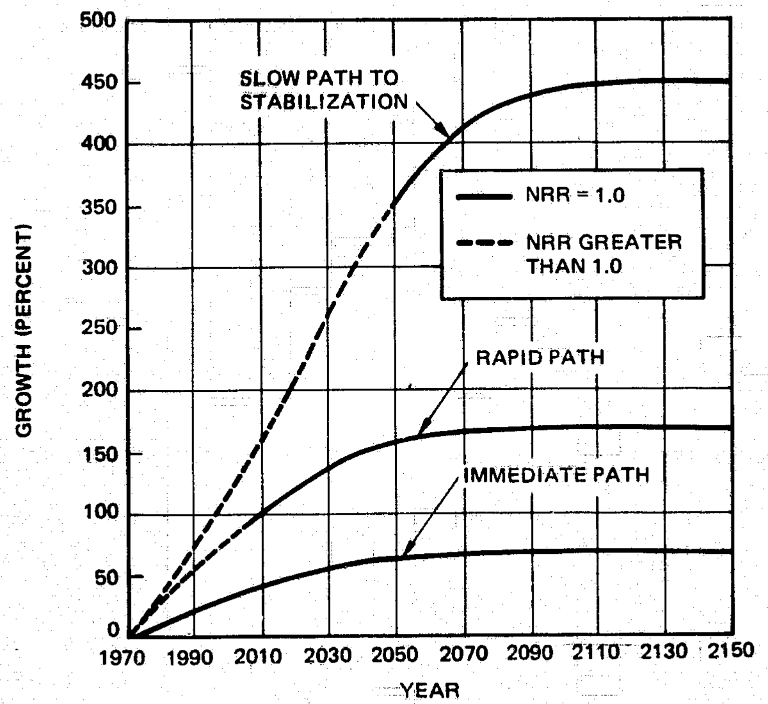
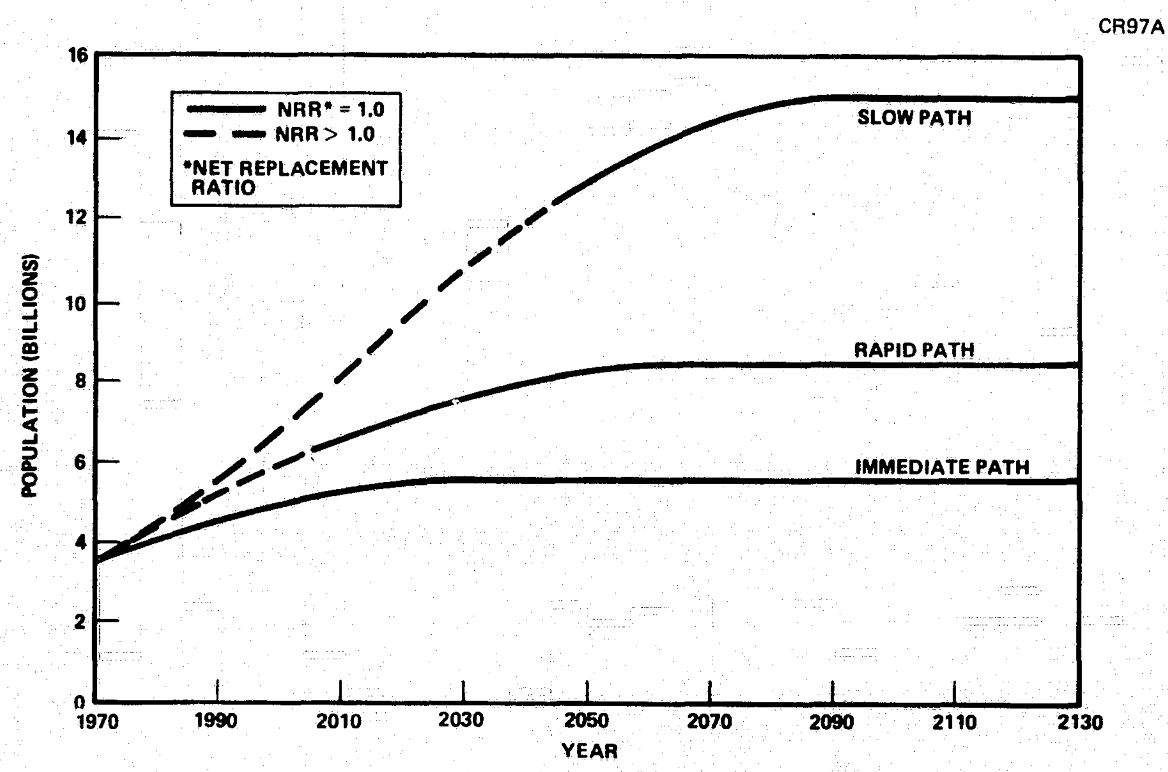


SOURCE: THE FUTURE OF POPULATION GROWTH-ALTERNATIVE PATHS TO EQUILIBRIUM, TOMAS FREJKA, WILEY, NEW YORK, 1973

Figure 3-3 Population Growth Potential of the Developing Regions, Selected Paths, 1970–2150

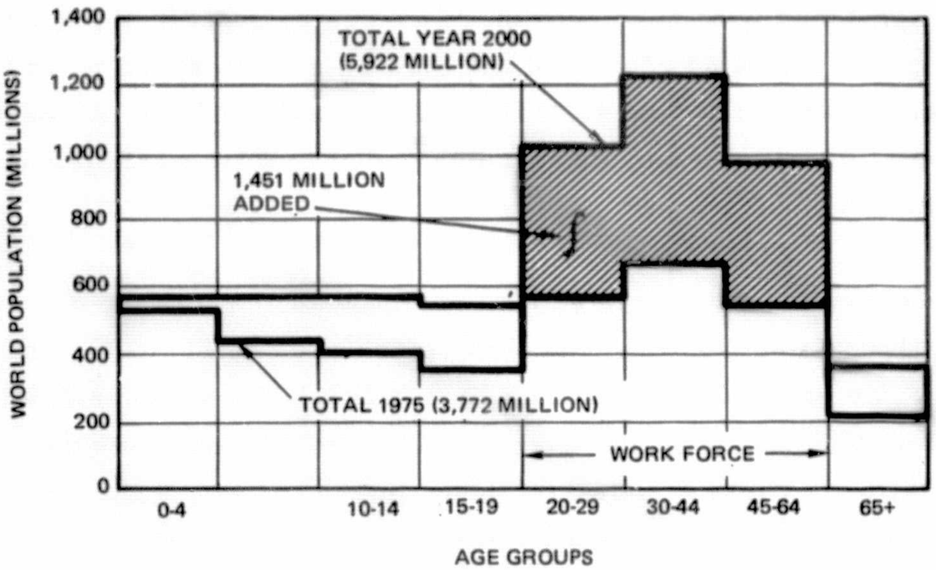
NRR of 1.0 is merely a vital preliminary for reaching a stationary population; it is not synonymous with zero growth. For Frejka's projections, the immediate path, the rapid path, and the slow path correspond to an NRR of 1.0 being achieved by the years 1975, 2000-05, and 2040-45, respectively. The extrapolations of these projections extended to total world population are presented in Figure 3-4.

Figure 3-3 shows the enormous growth potential of the less developed countries. Even if an NRR of 1.0 could be achieved by 2000-05, and taking into account age structure (Reference 1, pp 52-81), by the year 2000 some 1,451 million inhabitants in the age group of 20 to 64 would be added to the world population. These trends are shown in Figure 3-5. The age group of 20 to 64 represents not only the main work force of the population, but also the major political and economic power groups in the world. Observe that for a projection to the year 2000 most of the added 1,451 million persons are alive today.



SOURCE: TOMAS FREJKA, THE FUTURE OF POPULATION GROWTH: ALTERNATIVE PATHS TO EQUILIBRIUM, 1973

Figure 3-4. Growth Potential of the World Population



SOURCE: THE FUTURE OF POPULATION GROWTH-ALTERNATIVE PATHS TO EQUILIBRIUM, TOMAS FREJKA, WILEY, NEW YORK, 1973

Figure 3-5. Trends in World Population — Projection for NRR = 1 by 2000—2005

Future Needs of the Developing Regions

The 1,451 million also represent the class that will present the greatest social, political, and economic demands on the world's resources over the next 25 years. Realizing that at least two-thirds of these individuals reside in the developing areas, tremendous demands will be placed upon the globe to produce not only the basic necessities of life, but also advances in the standard of living. The interactions of man and his required resources are presented in Figure 3-6, which shows that the 1,451 million are caught up in a revolution of rising expectations where economic growth is an irreversible and irrespressible need. When translated to socioeconomic terms, this growth will require expanded capabilities in the areas of education, social demands, information transfer, environmental protection, disaster avoidance, food and fibre, transportion, shelter, and energy. In the area of education, increased requirements for learning will place a tremendous burden on the educational institutions of the developing nations, perhaps requiring radical and innovative approaches to reach the masses of people involved.

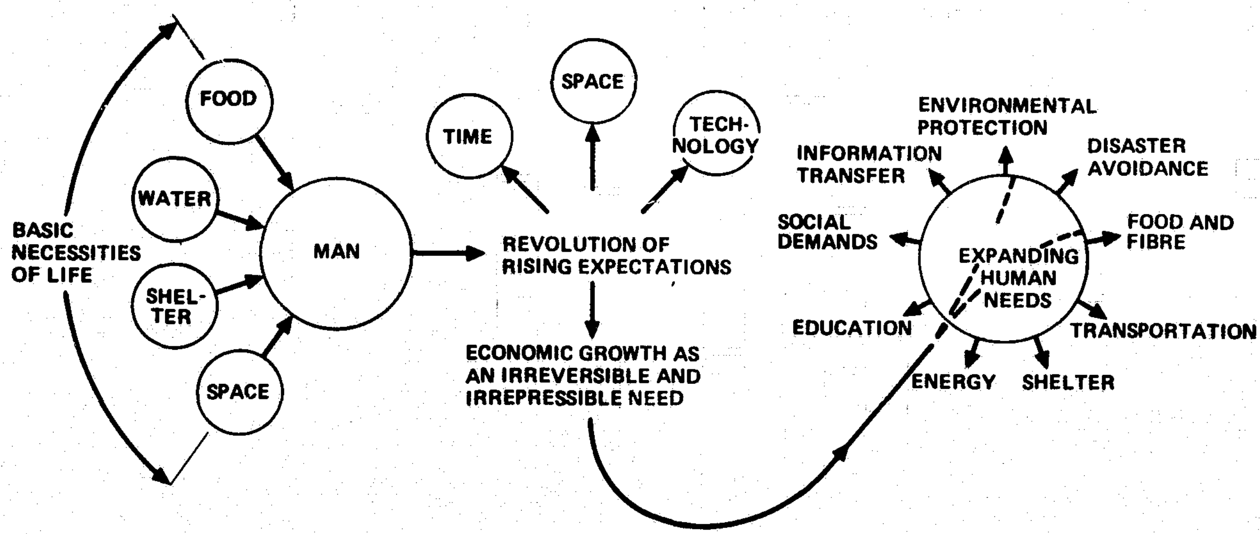


Figure 3-6. Interaction Between Man and His Resources

Another problem of serious concern to "futurist" researchers is world food production and distribution. Agronomy has advanced to the point where the production of crops, assuming the proper availability and application of technology, can meet the needs of the growing population in total. The problem lies in the distribution of products to the market place on a timely basis. Futurists see all food and farm products, assuming an emerging adequate transportation system, to have economic value Hence, there will be room for the "little guy" (i. e., South America and Africa) outside the major agricultural nations to profit by supplying to increasing demands on a worldwide scale. Therefore, there will be an ever-increasing demand for information on a two-way basis including data on weather conditions, surface water, soil conditions, and crop vigor, as well as oceanographic information.

The 1,451 million represent a tremendous user potential for space systems and especially the MOF. MOF can provide the basic disciplinary research and development capacity required in such areas as meteorology, earth sciences, physical sciences, communications, and astronomy. Advanced technology in these areas can provide, in the longer term, operational capa-

capabilities such as improved weather forcasts, disaster warnings, and low-cost communications to service the expanding demands and advancing standards of living throughout the world.

An example can be cited where MOF supported space/ground communications systems can provide a service to the developing market. Systems can be envisioned where the large and high-power elements of the network could be placed in space where unlimited access to solar power as an energy source is available. Direct to-the-home communications links (two-way circuits) could be established at significantly reduced per capita costs when compared to conventional land-line or ground point-to-point transmissions. MOF could serve to establish initially and maintain space communicating facilities. For example the manned assembly and servicing in space of the required very-large-scale antennas and solar energy collectors could be a function assigned to MOF. These systems could be tied in with other earth observation space platforms and payloads to provide educational services, farm information, weather forecasts, health care services, and food distribution information at very modest per-capita investments.

3.1.2 Long Range Weather Services

Accurate long-range weather forecasts available on a timely basis are basic to improved food production and distribution, hence the continuing improvement and development of this capability becomes an increasingly important area for research. As Mark Twain so sagely observed, "Everybody talks about the weather but nobody does anything about the weather." Space technology now offers the potential means to do something about the weather.

As an example of the economic consequences of storm systems, Figure 3-7, based on National Weather Service statistics, portrays the reported and/or estimated property damage caused by North Atlantic tropical cyclones (hurricanes) in the US. The 70-year period plotted on the chart follows an upward trend of a 14 percent annual rise as well as the natural cyclic annual occurrence of hurricanes experienced. By the year 1970, the damage from hurricanes was reaching the $5 billion level and steadily increasing. As meteorologists gain knowledge on how to avert this damage by perhaps better

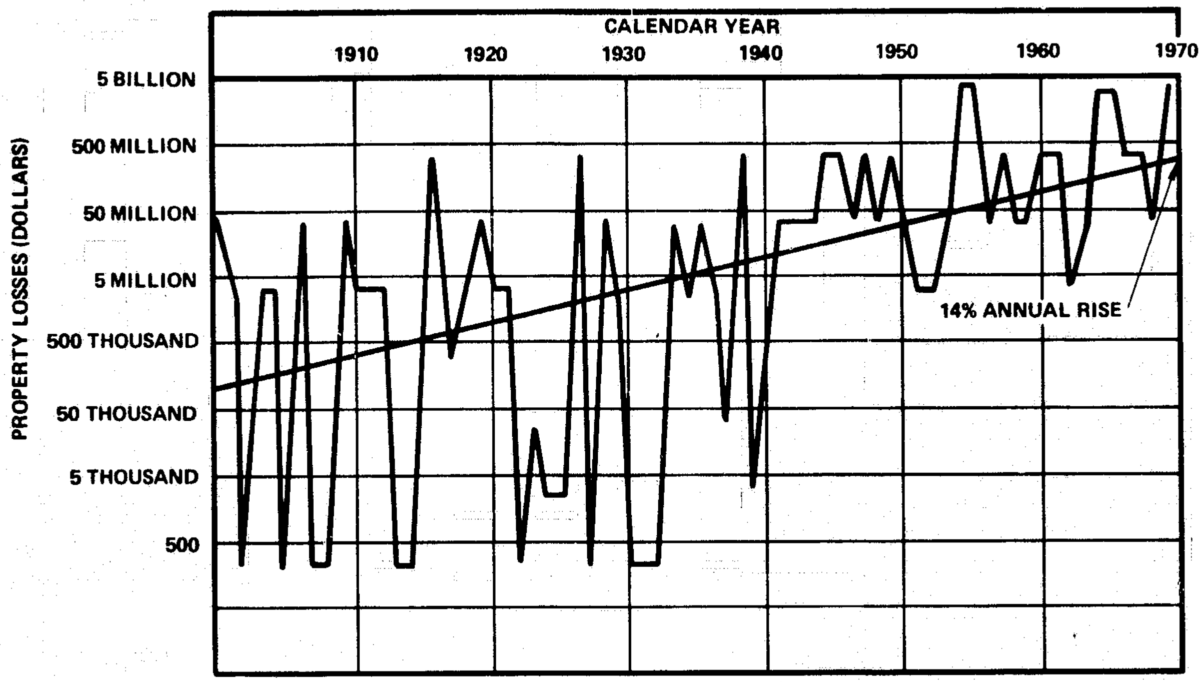


Figure 3-7. 70-Year Trend of Property Damage Caused by North Atlantic Tropical Cyclones (Weather Bureau Statistics)

understanding the process that causes these giant storms to develop, modification techniques can be expected to evolve to reduce and/or eliminate these staggering annual losses.

Tornadoes offer little advance warning and, unlike other destructively severe storms such as hurricanes which can be tracked for days before reaching populated areas, are characterized by rapid onset and heretofore unpredictable destruction paths. Study of tornadoes is aimed at understanding the basic atmospheric mechanisms that produce them. Also, attempts to identify indicative phenomena that can be measured and/or observed to predict their occurrence are in the early research phase. This research has clearly shown that many meteorological parameters need to be observed on a nearly continuous basis.

Figure 3-8 describes the time-space scales of several atmospheric phenomena and storms. The tornado occupies a time-space relationship as shown on the chart that required nearly continuous observations on a limited spatial scale. Tornado observations would be required nearly every 30 seconds at 100-meter

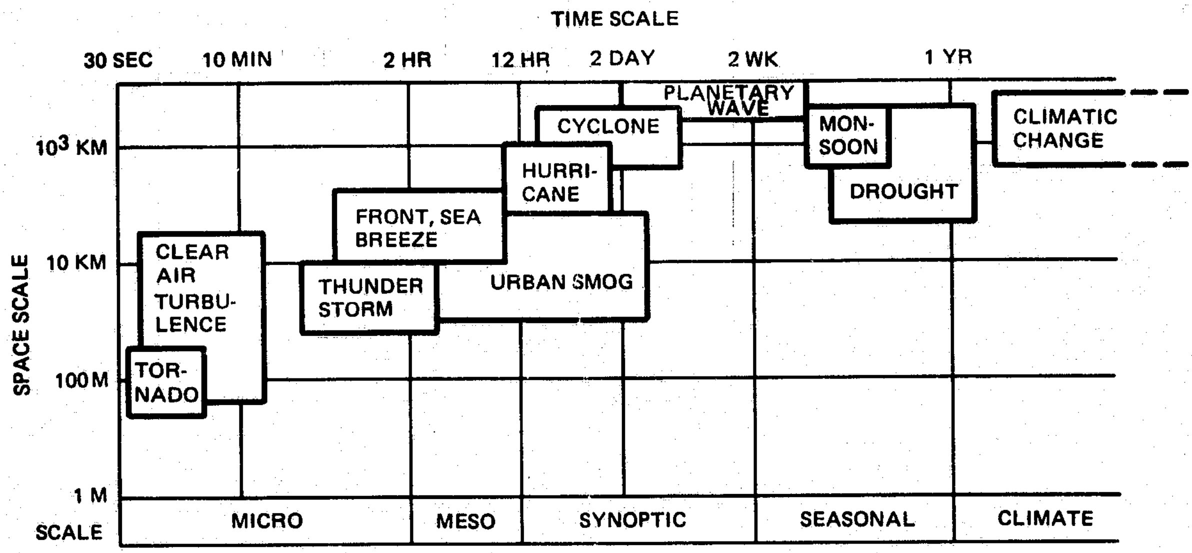


Figure 3-8. Atmospheric Phenomena

resolution. The temporal and spatial coverage requirements defined by considerations thus define overall observation requirements. Therefore, if these phenomena are to be monitored and observed from space, a geostationary vantagepoint (a geosynchronous MOF) is a necessity.

The temporal and aerial coverage parameters have to be taken into consideration as well as the geometric relationships of the observer-target. As shown in Figure 3-9, the target (for example, a tornado track on the ground) displays anistropic optical scattering while the background is characterized by uniform (Lambertian) scattering. In this situation, which was verified by aerial photography, if the target is viewed along the sun line it will appear brighter than its surroundings because of its relatively strong backscattering. Similarly the same target will appear darker if viewed from the position shown at the right of the chart. Notice that the target will not be visible directly overhead where the reflectance from the ground coincides with the reflectance from the target. Therefore, if the target is to be observed, it is appropriate to view it

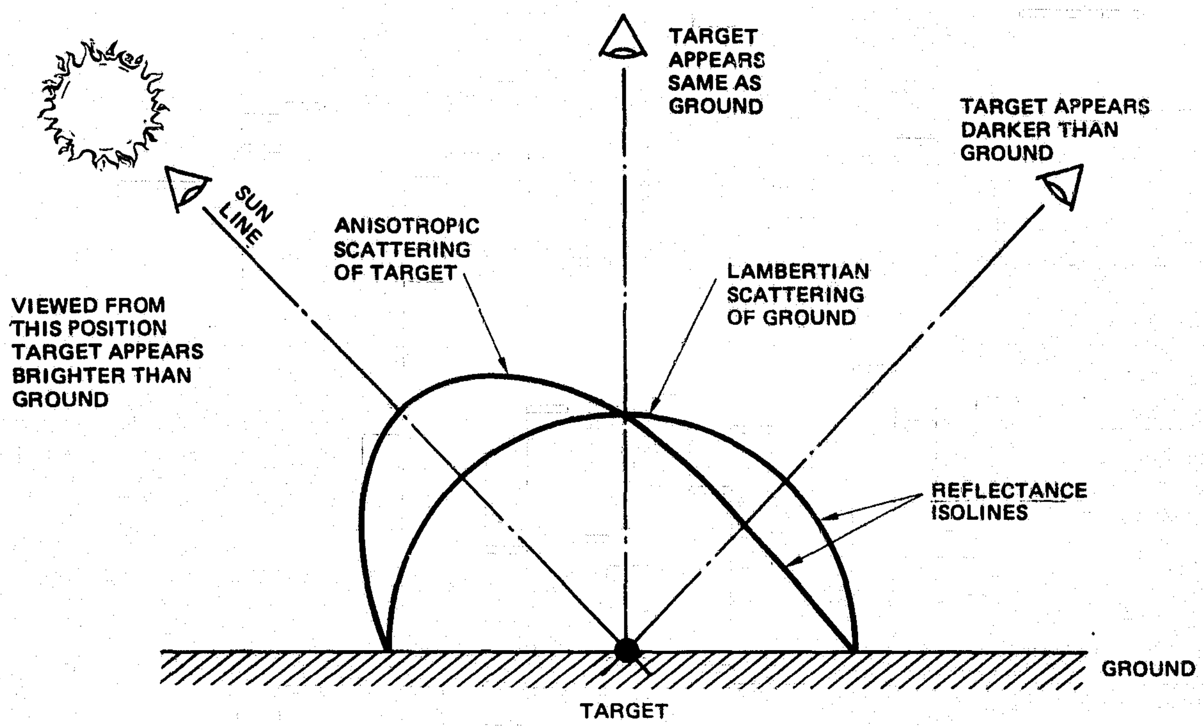


Figure 3-9. Importance of Viewing Geometry in Distinguishing Features

either along the sunline or at right angles to the ground when the target can be discriminated against the background. This example illustrates the importance of establishing a proper viewing geometry. A geosynchronous observatory has the decided advantage since a wide range of viewing geometries is available during the course of diurnal cycle.

The users contacted were strong advocates for an MOF placed in geostationary orbit, properly outfitted with remote sensors, and diffraction limited multispectral optical instruments, and most important, having a trained human observer onboard. A human observer would be most useful in studying hail, heavy rain, and tornadoes where time and space information at the proper scales need to be integrated by the human intellect. By means of zoom optical telescopes, the onboard observer could focus on areas of interest and determine the information required in terms of intervals between photographs of images, spectral ranges, and time resolution parameters. When a better understanding is achieved the requirements for automated satellites can be established, which in turn can serve as warning outposts

for severe storms hazardous to shipping, crop production, and structures. In the case of a space meteorological research station, ideally, the MOF crew makeup would include, in addition to meteorologists, an individual to act as a flight engineer, technician, and troubleshooter to support the night and day weather-watching chores of the specialists. For a weather facility devoted to tornado research, a 90-day flight duration would best be spread over the months of March, April, and May — the tornado season. With discoveries made from a geosynchronous MOF, early warning mechanisms that would alleviate the great personal loss and suffering presently being experienced by thousands of persons each year in this country could be developed. The savings in life and property alone could more than offset the expense of equipping and staffing the MOF with the required payloads and crew.

3.1.3 Advanced Technology Applications

In the area of advanced technology applications, there are a number of very interesting and promising possibilities. During the course of the basic MOSC study, one area defined as a new payload concept for manned facilities was that of assembly of large space structures in space. The example cited was the deployment of the 200-meter radio telescope after initial buildup in orbit by manned operations supported from the manned orbital facility. There are other structures offering similar advantages to the manned assembly approach. One of these is the Satellite Solar Power System (SSPS).

One of the more ambitious concepts for economic exploitation of space is found in the SSPS which has been an object of study[3] over the past several years. This very ambitious approach has the potential to provide an economically viable and environmentally and socially acceptable option for power generation on a scale substantial enough to meet a significant portion of future world energy demands.[4] The concept involves an evolution of configurations of the SSPS ultimately reaching a 25 million pound facility in geosynchronous orbit providing 5,000 megawatts of power on earth. The

(3) Feasibility of a Satellite Solar Power Station, NAS3-16804, Arthur D. Little, Inc., NASA CR-2357, February 1974, NTIS N74-17784.

(4) The Satellite Power Station: An Option for Energy Production on Earth, Peter E. Glaser, Arthur D. Little, Inc., 1975.

facility acquisition plan involves three major phases. Initially a technology development and verification phase would gain experience in component development and space assembly of a 10- to 50-megawatt facility in the 250,000-pound class. The second step would concentrate on the development of a pilot-size SSPS (200 to 750 megawatts, 2 million pounds), built to deliver useful power to earth from geosynchronous orbit. The ultimate phase would involve the construction of the full-scale SSPS, hopefully before the year 2000.

The potential offered by MOF to support the development phases and SSPS buildup is outstanding. The very large structures required, even during the technology development phase, are potential candidates for manned assembly in space. To illustrate, post-mission design evaluation of the Skylab orbital workshop suggested that possibly a 15 percent weight savings might have been possible if the solar panels had been erected manually rather than automatically. An analogous situation might be found in a manned assembly approach to the SSPS. A weight savings of 15% in a 250,000 pound 10- to 50-megawatt facility would represent a significant logistics improvement.

3.1.4 Space Processing and the Industrialization of Space

The experts contacted in the space processing field believe that ultimately space processing payloads will provide greater growth potential than other payload areas. By 1990, some pilot-plant production operations can be expected. Separately and privately owned payload modules might be commonplace after this time frame.

Speculation was made as to the types of facilities that would be required to support MOF space processing operations in the transition phase. While it is not possible to forecast with any degree of certainty the exact types of materials and substances that will be involved in this period, there is a concensus on the general requirements of the facility. These would include:

A. High-temperature (2,500°C) furnace with levitation capabilities.
B. Low-temperature (1,300°C) furnace.
C. Special crystal growing facility.
D. Separate processing facility for glasses and transparent oxides.
E. Electrophoresis separation facility together with bacteria growth and culture facility

F. General purpose laboratory for chemical processes.

G. Solar furnace.

H. Power levels: 10 minutes – 30 kW, 1 hour – 18 kW.

I. Liquid cooling system, thermal capacitor, double heat exchange loops to space radiator.

3.1.5 Space Colonization

The future requirements for colonization of space can present some very long-term planning aspects for manned missions in the years to come. This subject was addressed by a summer study held during July and August of 1975 at the Ames Research Center. The participants in this study included some 28 faculty, student, and volunteer visitors from colleges, universities, and industry from a cross-section of the country.

As reported in Appendix A, the study group identified a number of technical questions that required answers before a colony could be designed. The majority of these questions could be answered by the life science laboratories and the supporting technology payloads that are candidate MOF mission activities. For the most part, the investigations required to provide the answers would benefit by the extended flight durations offered by MOF.

3.1.6 Scientific Research in Geosynchronous Orbit

There has been an increase in interest recently[(5)(6)] on the part of the scientific community in a geosynchronous manned facility. An area where a distinct advantage is expected is an outgrowth of the atmosphere, magnetosphere, and plasmas in space (AMPS) payloads.

One part of the research plan for AMPS payloads involves investigations of the region surrounding the spacecraft after the introduction of active perturbations of the natural environment. At first the logical choice of orbital parameters favors low earth orbits (~200 nmi). At these altitudes, the plasma is predominantly a low-energy cold population with an occasional input

[(5)] Remarks on Scientific Missions for a Geosynchronous Space Station, C. A. Lundquist, unpublished paper, MSFC, 26 June 1975.
[(6)] AMPS Experiments Conducted at Geosynchronous Orbit, R. Chappell, unpublished paper, MSFC, 1975.

of energetic particles. While the sensors and instruments developed for low-altitude AMPS missions are suitable for later use at geosynchronous altitude, substantially different conditions and phenomena are expected. At synchronous altitude the plasma population can vary from dominantly cold in the local time regions around dusk to energetic in the midnight or dawn sector. Hence, similar measurements at the higher altitudes at the far reaches of the atmosphere would be complementary to the low-altitude work.

Typically, the geosynchronous orbit activities could include chemical release experiments in the equatorial plane supporting new wave-particle interaction investigations; the electron bounce experiment that serves as a field line tracer of the magnetosphere; correlation between low-altitude processes, such as the aurora, and high-altitude phenomena such as the plasma sheet and ring current; and injectors of tracer chemicals to paint the magnetic field lines. Further, large-scale, global, synoptic observations of the overall dynamics of the aurora would be exciting new dimensions added to the AMPS research.

Long baseline interferometry approaches to radio astronomy are further examples of geosynchronous altitude desirability. On earth these measurements are limited to baseline distances of less than one earth diameter. A system with one radio telescope on earth and another at a geosynchronous location would not only benefit from a baseline distance of some 20,000 miles but also profit from possibilities of real-time correlation analysis of simultaneously received signals. With such a system it is envisioned that measurements of the structural details of complex radio sources could be made with spatial resolution unobtainable on the surface of the earth.

Similarly, advanced technology possibilities for extension of long baseline interferometry to infrared and optical frequencies would expand general astronomical capabilities enormously. Astronomical objects could be studied with spatial resolution unrealizable from the earth.

Other questions important to the scientific community could be included in the geosynchronous MOF scientific repertory. One of the most interesting contemporary controversies in the astrophysical field is the origin of recently

discovered gamma-ray bursts. Study of these phenomena is most attractive using interferometry observations conducted from the facilities. Also study of artificial comets could be facilitated. Continuous contact with earth-bound astronomers would be a most desirable advantage.

3.2 REVIEW OF RELATED STUDY FINDINGS

In addition to the material gathered from the individuals contacted regarding potential new uses of MOF-class facilities, the documented results of several current planning studies were examined during the course of the study. These studies provided important insights as to the identification of future mission goals and objectives. These identified future objectives should be considered candidate MOF payload and mission requirements. The three studies examined most extensively included (1) Practical Applications of Space-1974 Snowmass Summer Study, (2) Outlook for Space - Interim Results (Hearth Committee) May 28, 1975 and (3) Aerospace Study of Commonality of Space Vehicle applications to future national needs.

During the month of July 1974, and under the auspices of the Space Applications Board (SAB) of the National Academy of Engineering, a study[7] was conducted of the practical applications of space systems. The study members, under the direction of Colorado Governor Jack M. Campbell, met in Snowmass, Colorado. Most of the members of the SAB participated in the discussions and were joined by a number of individuals drawn from federal, state, and local governments, business and industry, and the academic community. Organized into 14 panels, approximately 70 senior and experienced users participated in the study and their findings are now available. Generally, the study concluded that to satisfy the information and service needs expressed by the user panels will require, in addition to facilities in nominal 28.5° inclination orbits, space facilities in either polar or geosynchronous orbits. Further, the study described an important transitional stage between research and development

(7) Practical Applications of Space Systems, A Study by the Space Applications Board of the Assembly of Engineering, National Research Council, National Academy of Sciences, Washington, D.C. 1975

and the implementation of operational applications systems. During the transitional phase it is important that the user commumity have an opportunity to try the system and to determine its adequacy as a replacement or supplement to other methods. For future space systems potential users need to have adequate opportunity to evaluate new services. The SAB Snowmass summer study was a source of valuable insights into user needs forecasted for Shuttle-era capabilities.

Another source of future needs is found in the preliminary results of the "Outlook for Space" study(8) under the direct of Donald Hearth, GSFC. Many organizations including Government agencies, nonprofit corporations, technical societies, industrial associations, and selected advisory committees provided solicited inputs to this study. In addition, many unsolicited inputs were made by many individuals representing a broad spectrum of both the private sector and the Government. Further, working groups were consulted concerning specific issues on the future environment, earth-oriented activities, and extraterrestrial activities including support from the Smithsonian Institute and many universities both domestic and foreign. The tentative conclusions of this study are outlined as follows:

1. Space can contribute to the solution of a wide range of future problems; it provides a means to an end; space can contribute to material and intellectual needs of mankind.
2. Change in program emphasis is envisioned; increase resources for material problems on earth.
3. Need for transference of knowledge and technology exists; active NASA role required.
4. Cost-benefit considerations should have a role in planning the R&D phase.

B. Applications

1. Increase both R&D and operational remote-sensing systems; not one without the other.
2. Multiple use of remote-sensing data from same sensors.

(8) <u>Review of Interim Results</u>, Outlook for Space, May 28, 1975

3. Importance of climate.
4. Need for R&D on solar power and hazardous waste disposal.
5. Need for advancement in US of technology and its demonstration for communications satellites.
6. Exploit potential of space environment; commercial space processing possibility.
7. Need for increasing involvement of private enterprise.
8. Need for broader scientific foundation and benefits from earth sciences.
9. Increasing need for NASA to work with Federal and state agencies, ultimate users, and the international community.

C. Space Science
1. Focus on fundamental questions; need for public perception of importance.
2. Need for data analysis and theoretical studies in certain disciplines.
3. No consensus in study group on when and how to search for intelligent extraterrestrial life.

D. Manned Activities
1. Man is an essential part of a viable space program.
2. Man will explore, occupy, and exploit new frontiers; major manned exploration or colonization forecast beyond next few decades.
3. Small permanent space station next step.

E. Technology
1. Need for technology advance for large fraction of future missions.
2. Need for data/information management and interpretation/models.
3. Maintain technology base to exploit future opportunities.

The contracted study[9] of the Commonality of Space Vehicle Applications to Future National Needs conducted for NASA by the Aerospace Corporation (NASw-2727) provided the identity of developments and technology likely to

(9) Study of the Commonality of Space Vehicle Applications to Future National Needs, contract NASW 2727, Aerospace Corporation, El Segundo, Calif. March 1975.

be required by NASA and DoD in common to support tentative space programs through the end of the century. The study examined the following issues although consideration was given in the MOF User Analysis only to the aspects of the civilian requirements set forth:

A. Identify likely national and space goals in the time period.
B. Collect new space initiative opportunities.
C. Develop a long-range planning methodology based on applicable portions of the DoD process.
D. Structure alternate space program plans.
E. Emphasize military planning, to complement in-house NASA studies.

Another important product of the Aerospace Study was the delineation and description of 28 initiatives (payloads) directly traceable to space functional requirements and in turn to national goals in public service, and humanistic, intellectual, and materialistic categories in the civilian areas. In the description of these initiatives the report contains the identification of what is termed "building block and technology requirements". These requirements include the identification, among other requirements, of on-orbit assembly, servicing, and manned space station support. This information was most useful for the purposes of the identification of future MOF mission requirements.

Another source[10] that was useful in identifying future mission requirements for the assembly of large space structures was the OAST Space Technology Workshop document. There were also other technology advances described in the workshop briefing materials that might well be considered in the planning of future missions. The majority of these advances required a multi-discipline approach to the achievement of the capability. There were 11 categories of space technology interest areas, identified by the individuals participating in the study. These categories are as follows:

Data Processing and Transfer
Sensing and Data Acquisition
Navigation Guidance and Control
Power

(10) OAST Space Technology Workshop Briefing Charts, Madison College, Harrisonburg, Va, August 15, 1975

Propulsion

Structures and Dynamics

Materials

Thermal Control

Entry

Basic Research

Life Support

3.3 CORRELATION OF USER NEEDS AND SPACE APPLICATION OBJECTIVES

The suggestions voiced by the potential users contacted and the requirements as cited by the studies examined were compiled and presented across the abscissa of the matrices shown in Figures 3-10 through 3-13. The ordinate of the figures represent the categorized MOF mission activities presented initially in Section 2.2. The defense-oriented requirements and corresponding

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	MAJOR MISSION ACTIVITIES																								
	1					2				3				4					5				6		
NEW USER NEEDS FROM INDIVIDUAL CONTACTS	A	B	C	D	E	A	B	C	D	A	B	C	D	A	B	C	D	E	A	B	C	D	A	B	C
ACADEMIC INSTITUTIONS																									
FUTURES RESEARCH/DEMOGRAPHY						●	●		●			●	●				●								●
MESOSCALE METEOROLOGY							●			●															
ADVANCED SPACE TECHNOLOGY								●											●						
TECHNOLOGICAL FORECASTING						●	●							●					●	●					
SPACE COLONIZATION		●	●	●	●			●	●					●	●	●	●	●	●	●		●	●	●	
INDUSTRIAL ORGANIZATIONS																									
CIVILIAN SPACE INITIATIVES												●				●	●	●	●	●		●			
SPACE PROCESSING								●						●											
PILOT-PLANT PRODUCTION IN SPACE								●						●											
COMPONENT MANUFACTURING IN SPACE														●								●			
SPACE POWER STATIONS																●							●		
SPACE VEHICLES														●					●	●	●	●			
SKYLAB ASTRONAUTS																									
SCIENCE PILOT – MEDICAL		●			●					●	●										●		●		
PILOT–EARTH OBSERVATIONS	●					●	●			●	●								●				●		
PILOT–STATION OPERATIONS	●							●		●	●								●	●			●		
OTHER AGENCY																									
MULTI-NATIONAL COOPERATION	●				●	●	●							●										●	●
INTERNATIONAL SPACE SCIENCES																								●	●
BENEFIT TO NATION AND MANKIND					●			●						●	●								●		
SPACE ASSEMBLY/LARGE SPACE STRUCTURES/ SPACE TECHNOLOGY	●		●						●			●				●	●		●						

1 – BASIC RESEARCH
A – ASTRONOMY
B – SOLAR PHYSICS
C – SPACE SCIENCES
D – HIGH-ENERGY ASTROPHYSICS
E – LIFE SCIENCES

2 – APPLIED RESEARCH
A – EARTH RESOURCES
B – METEOROLOGY
C – MATERIALS/ PROCESSES
D – COMMUNICATIONS/ NAVIGATION

3 – INFORMATION SERVICES
A – STUDENT EXPERIMENTS
B – TV DEMONSTRATIONS
C – POINT-TO-POINT COMMUNICATIONS
D – BROADCASTING

4 – COMMERCIAL OPERATIONS
A – MANUFACTURING
B – HIGH-VACUUM OPERATIONS
C – SPACE POWER
D – COMMUNICATIONS
E – SPACE STORAGE

5 – SERVICE OPERATIONS
A – ASSEMBLY, LARGE STRUCTURE
B – SATELLITE SERVICING
C – TUG OPERATIONS
D – SATELLITE COMMAND/ CONTROL

6 – GOVERNMENT OPERATIONS
A – NATIONAL PRESTIGE
B – INTERNATIONAL MISSIONS
C – DETERRENT TO CONFLICT

Figure 3-10. Correlation of MOF Mission Activities to Individual Contacts

SPACE VEHICLE APPLICATIONS INITIATIVES TO FUTURE NATIONAL NEEDS (AEROSPACE STUDY NASW 2727)	MAJOR MISSION ACTIVITIES 1					2				3				4					5				6		
	A	B	C	D	E	A	B	C	D	A	B	C	D	A	B	C	D	E	A	B	C	D	A	B	C
OBSERVATION																									
RESOURCES/SURVEYS/POLLUTION MAPPING						●	●												●	●			●		
ENERGY MONITORS						●																			
INTERNATIONAL SENSORS																			●	●				●	●
TRAFFIC SENSORS												●					●		●	●					
COMMUNICATIONS																									
EMERGENCY/POLICE												●					●		●	●					
GOVERNMENT SERVICES																	●		●	●			●	●	
PERSONAL SERVICES												●	●				●		●	●					
INTERNATIONAL																	●			●			●	●	
NAVIGATION																	●		●	●					
SUPPORT																									
ENERGY DELIVERY																●			●	●		●			
ENVIRONMENTAL CONTROL																				●					
TRAFFIC CONTROL																				●					
MARKERS/AIDS																									

1 – BASIC RESEARCH
A – ASTRONOMY
B – SOLAR PHYSICS
C – SPACE SCIENCES
D – HIGH-ENERGY ASTROPHYSICS
E – LIFE SCIENCES

2 – APPLIED RESEARCH
A – EARTH RESOURCES
B – METEOROLOGY
C – MATERIALS/PROCESSES
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A – ASSEMBLY, LARGE STRUCTURE
B – SATELLITE SERVICING
C – TUG OPERATIONS
D – SATELLITE COMMAND/CONTROL

6 – GOVERNMENT OPERATIONS
A – NATIONAL PRESTIGE
B – INTERNATIONAL MISSIONS
C – DETERRENT TO CONFLICT

Figure 3-11. Correlation of MOF Mission Activities Future National Needs (Aerospace Corporation)

THEMES SUGGESTED BY OUTLOOK FOR SPACE COMMITTEE	MAJOR MISSION ACTIVITIES 1					2				3				4					5				6		
	A	B	C	D	E	A	B	C	D	A	B	C	D	A	B	C	D	E	A	B	C	D	A	B	C
EARTH ORIENTED																									
PRODUCTION AND MANAGEMENT OF FOOD AND FORESTRY RESOURCES (THEME 01)						●	●																	●	
PREDICTION AND PROTECTION OF THE ENVIR (THEME 02)		●	●			●	●																	●	
PROTECTION OF LIFE AND PROPERTY (THEME 03)						●	●		●															●	
ENERGY AND MINERAL EXPLORATION (THEME 04)		●	●			●	●									●		●						●	
TRANSFER OF INFORMATION (THEME 05)									●			●	●											●	
USE OF ENVIRONMENT OF SPACE FOR SCIENTIFIC AND COMMERCIAL PURPOSES (THEME 06)	●	●	●	●	●	●	●	●	●					●										●	
EARTH SCIENCE (THEME 07)		●	●			●	●																	●	
EARTH—TERRESTRIAL																									
NATURE OF THE UNIVERSE (THEME 08)	●	●	●	●	●																				
FATE OF MATTER (THEME 09)	●			●																					
LIFE CYCLE OF SUN AND STARS (THEME 10)	●	●																							
EVOLUTION OF THE SOLAR SYSTEM (THEME 11)		●		●																					
ORIGINS AND FUTURE OF LIFE (THEME 12)	●			●	●																				

1 – BASIC RESEARCH
A – ASTRONOMY
B – SOLAR PHYSICS
C – SPACE SCIENCES
D – HIGH-ENERGY ASTROPHYSICS
E – LIFE SCIENCES

2 – APPLIED RESEARCH
A – EARTH RESOURCES
B – METEOROLOGY
C – MATERIALS/PROCESSES
D – COMMUNICATIONS/NAVIGATION

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E – SPACE STORAGE

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A – ASSEMBLY, LARGE STRUCTURE
B – SATELLITE SERVICING
C – TUG OPERATIONS
D – SATELLITE COMMAND/CONTROL

6 – GOVERNMENT OPERATIONS
A – NATIONAL PRESTIGE
B – INTERNATIONAL MISSIONS
C – DETERRENT TO CONFLICT

Figure 3-12. Correlation of MOF Mission Activities to Outlook for Space Themes

	MAJOR MISSION ACTIVITIES																							
	1					2				3				4					5				6		
PRACTICAL APPLICATIONS OF SPACE SYSTEMS, SAB-NRC	A	B	C	D	E	A	B	C	D	A	B	C	D	A	B	C	D	E	A	B	C	D	A	B	C
USER-ORIENTED PANELS																									
WEATHER AND CLIMATE		●					●																		
USES OF COMMUNICATIONS									●			●	●				●								
LAND-USE PLANNING						●																			
AGRICULTURE, FORESTRY, AND RANGE MANAGEMENT						●	●																		
INLAND WATER						●																			
EXTRACTABLE RESOURCES						●																			
ENVIRONMENTAL QUALITY						●	●																		
MARINE AND MARITIME USES						●	●																●		
MATERIALS PROCESSING IN SPACE					●			●						●									●		

1 – BASIC RESEARCH
A – ASTRONOMY
B – SOLAR PHYSICS
C – SPACE SCIENCES
D – HIGH-ENERGY ASTROPHYSICS
E – LIFE SCIENCES

2 – APPLIED RESEARCH
A – EARTH RESOURCES
B – METEOROLOGY
C – MATERIALS/ PROCESSES
D – COMMUNICATIONS/ NAVIGATION

3 – INFORMATION SERVICES
A – STUDENT EXPERIMENTS
B – TV DEMONSTRATIONS
C – POINT-TO-POINT COMMUNICATIONS
D – BROADCASTING

4 – COMMERCIAL OPERATIONS
A – MANUFACTURING
B – HIGH-VACUUM OPERATIONS
C – SPACE POWER
D – COMMUNICATIONS
E – SPACE STORAGE

5 – SERVICE OPERATIONS
A – ASSEMBLY, LARGE STRUCTURE
B – SATELLITE SERVICING
C – TUG OPERATIONS
D – SATELLITE COMMAND/ CONTROL

6 – GOVERNMENT OPERATIONS
A – NATIONAL PRESTIGE
B – INTERNATIONAL MISSIONS
C – DETERRENT TO CONFLICT

Figure 3-13. Correlation of MOF Mission Activities to Future Practical Applications (1974 Snowmass Summer Study)

MOF utilization potential was not a consideration of this study. Even though this DoD-related area was not examined, by inference it could represent a level of facility requirements, equal to those of the civilian requirements.

The solid dots shown on Figures 3-10 through 3-13 represent a defined relationship between a user need on the one hand and an MOF mission activity on the other. There are entries in the matrix in which a possible relationship exists subject to further study and examination. For example, high-vacuum commercial applications where very large volumes of a high-quality vacuum environment can be economically useful are candidates for further exploration. Additionally, the operational roles of MOF in support of Tug operations such as refueling, staging in-orbit, payload interface verification, payload mating, clustering, and maintenance are worthy of consideration.

As a point of reference, the application areas encompassed by the payloads contained in the SSPDA are indicated on the matrix. While these areas were restricted primarily to scientific and technological applications, they form the basis and essential building blocks from which the other areas must emerge. A sound precursor program involving sortie and automated payload class missions must be considered a prerequisite to MOF utilization and exploitation missions. As cited in the NRC-SAB study, a well conceived research and development program followed by an adequate transition period, where the space systems handover to the user community can occur, is a must to the orderly buildup of economically justified and commercially attractive space operations. The role of MOF in this transitional phase can be most significant.

3.4 HIGH VALUE MISSIONS IDENTIFIED

Mission activities, where there is evidence of relatively high future interest, can be classified as high value missions. One measure of future interest developed during the course of the study was the frequency of occurrence of a particular mission activity as cited by the individuals contacted or by reference in one or more of the study sources examined. Figure 3-14 is a compilation of the data contained in Figure 3-10 through 3-13. The top nine major mission activities are flagged as the high value missions. The following table summarizes these high interest areas.

Area	Value
Earth Resources/Meteorology	Affects large segment of population - benefits to mankind
Point-to-point and personal communications	Large potential demand to be satisfied
Commercial space manufacturing	Economic payoffs in high technology markets
Commercial communications	Increase supply to meet demand at lowered cost
Assembly and servicing of payload in space	Adds major new dimension to space station capabilities
National Prestige and International Missions	New generation of public interest in space

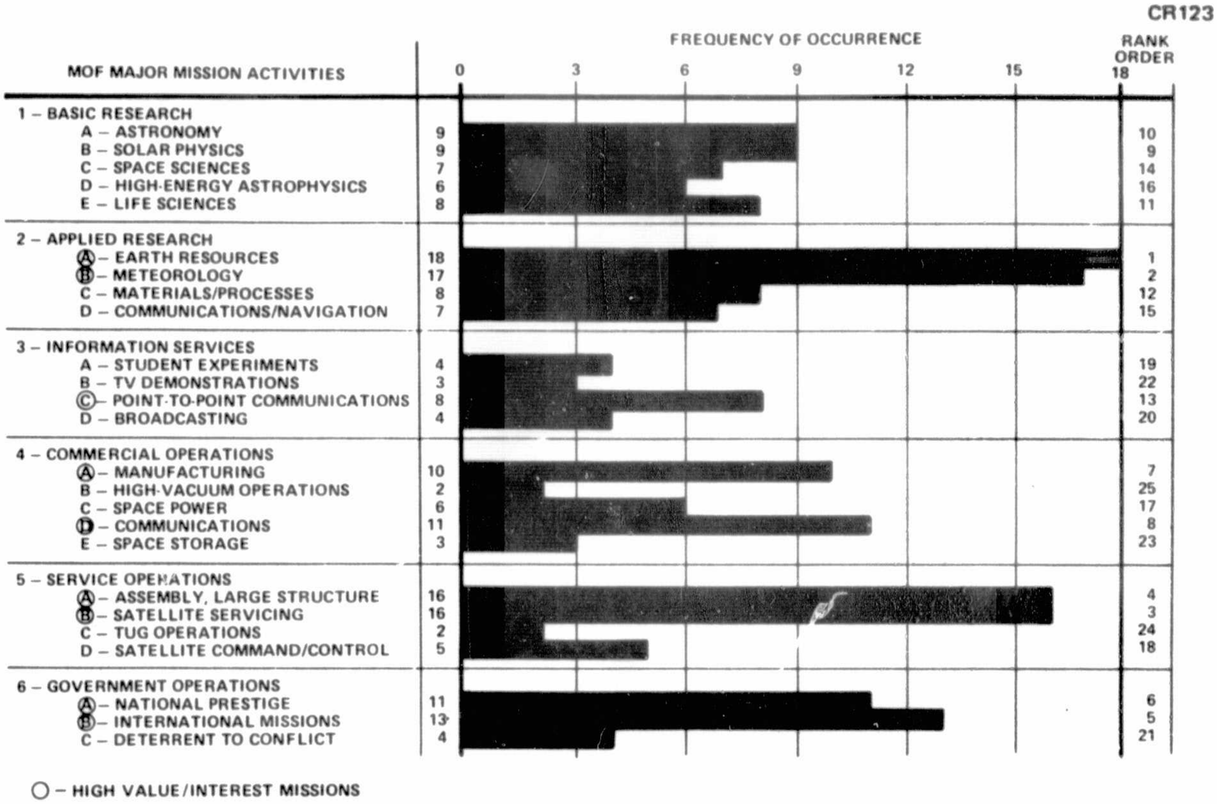

Figure 3-14. Distribution of User Needs

Section 4
MOF MISSION MODEL SCENARIOS

One of the key objectives of the MOSC User Analysis Task was to describe a preliminary mission model for MOF, or an early space station, for the 1985-2000 time period. It must be recognized that such a model is transient in nature and would only be valid at this specific point in time. Nevertheless, such a mission model serves as a point of departure for advanced planning purposes and can be very useful as a strawman around which critical issues can be identified and solutions proposed. Three different earth orbital capabilities were established for reference as follows: (1) a facility at 28.5-degree inclination, 200 nmi altitude in 1985; (2) a facility in polar orbit in 1987; and (3) a facility established in geosynchronous orbit in the 1990 time period. An overview of total program is shown in Figure 4-1. The initial timing for these three facilities is patterned after general budgetary and technological feasibility estimates derived in the basic MOSC Study and supplemented by data from the Aerospace Corporation study.

4.1 SYNTHESIS APPROACH

The logic flow portrayed in Figure 4-2 summarizes the various elements that were brought together in forming the MOF mission model. The initial time period represented in the model (1985-1991) reflect to a large extent the current planning for manned space missions as recorded in previous NASA mission models. The NASA October 1973 Space Shuttle Traffic Model prepared by the Shuttle Utilization Planning Office was used as a starting point in the study. The SSPDA was the primary source of payload definitions for the early time period. As noted on the chart, for the later period (1992-2000) it was necessary to draw upon information from individual contacts and more recently published reports in order to define the goals and objectives of these longer term missions.

Table 4-1 is a listing of 99 payloads which comprise the initial complement of payloads to be included in this cross-correlation matrix. The sources

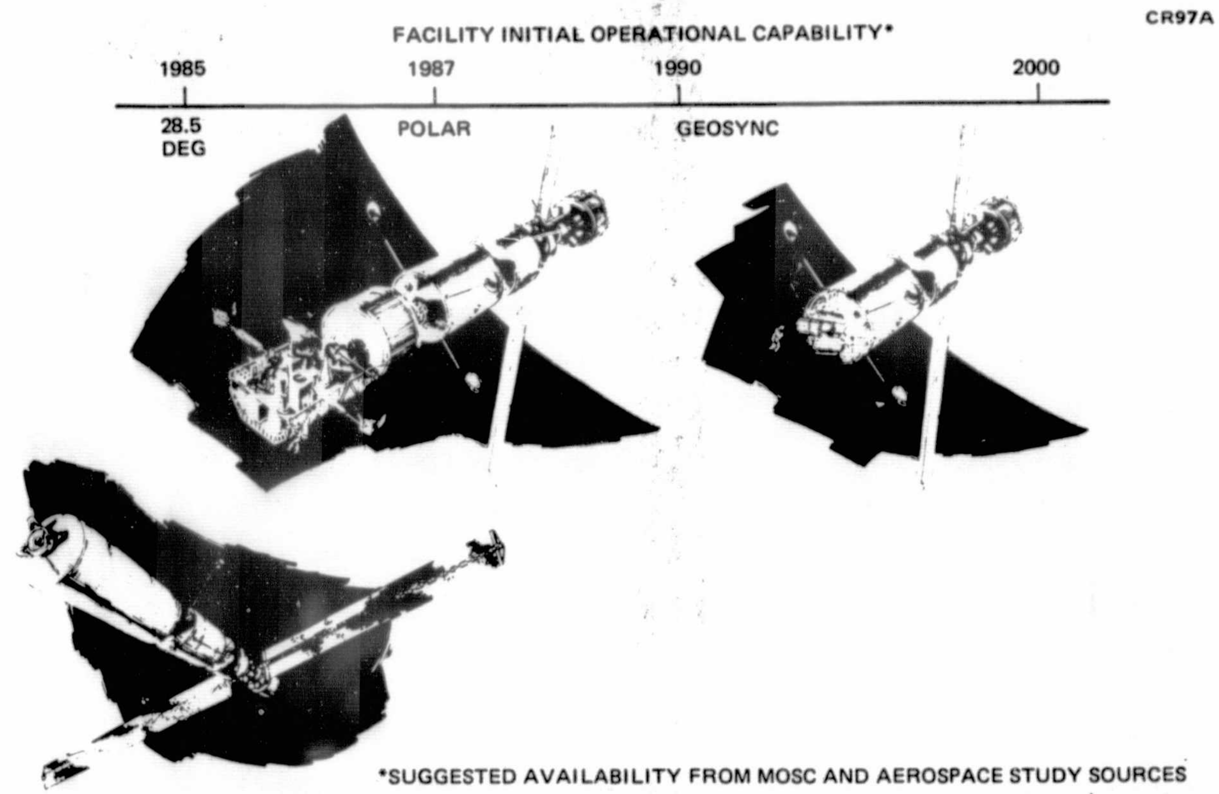

Figure 4-1. MOF Mission Model Overview

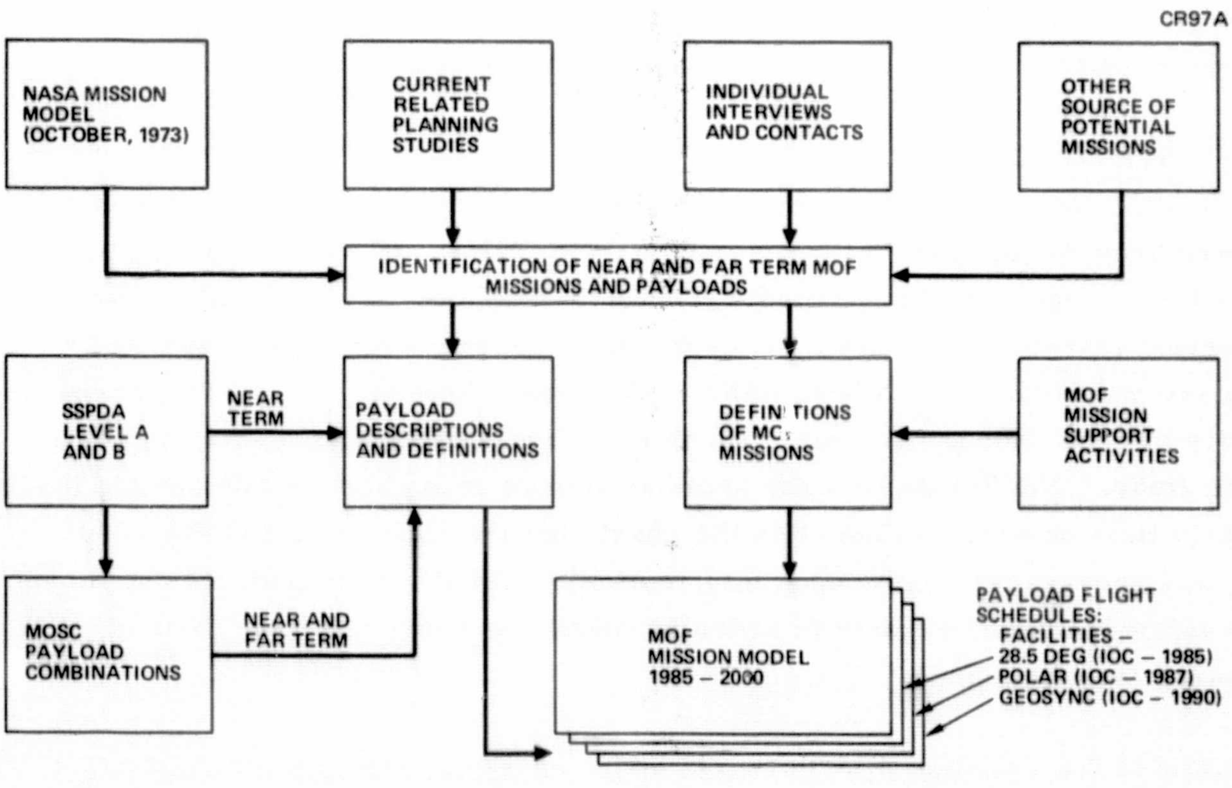

Figure 4-2. MOF Mission Model Development.

Table 4-1

PAYLOADS FOR THE MOF MISSION MODEL

Code*	Payload Descriptor	Wt (klb)	Vol (cu ft)	Power (kW)	Manhours/day in Orbit	Initiation Date	Orbital Requirements
AP-01A	Upper Atmosphere Explorer	2	129	1	2	1985	P
AS-01A	Large Space Telescope	25	1,420	2	12	1988	N
AS-05A	Advanced Radio Explorer	2	330	0	22	1985	S
AS-06S	Calibration of Astronomical Fluxes	4	30	0	24	1985	N
AS-07S	Cometary Simulation	42	114	1	24	1985	N
AS-09S	30M IR Interferometer	5	60	1	24	1985	N
AS-11A	1.5M IR Telescope	13	3,000	1	24	1987	N
AS-11S	Polarimetric Experiments	0	10	0	12	1985	N
AS-12S	Meteoroid Simulation	5	80	1	12	1985	N
AS-13A	UV Survey Telescope	7	1,400	1	24	1986	N
AS-14A	1m UV-Optical Telescope	8	303	1	24	1987	N
AS-17A	30m IR Interferometer	7	9,778	1	24	1987	N
AS-18S	1.5km IR Interferometer	12	45	1	24	1985	N
AS-20S	2.5m IR Telescope (Cooled)	9	33	0	24	1989	N
AS-50S	Combined UV/XUV	6	22	0	24	1986	N
CC-01	Global Search and Rescue	2	60	0	4	1985	S
CC-02	Urban/Police Wrist Radio	8	1,700	1	4	1990	S
CC-03	Disaster Control	8	1,700	1	4	1990	S
CC-04	Electronic Mail Transmission	8	1,700	10	4	1990	S
CC-07	Voting/Polling	8	1,700	1	4	1990	S
CC-08	National Information Service	8	1,700	10	4	1990	S
CC-09	Personal Communications	9	1,900	21	4	1990	S
CC-10	Diplomatic Hotlines	3	2,500	1	4	1985	S
CN-05S	Laser Communications Experiment	0	224	1	7	1985	P
CN-07S	Large Reflector Development	4	2,650	0	4	1985	P
CN-08S	Open Travelling Wave Tube	0	2	0	1	1985	N
CN-12S	Intefer. Navigation and Surveillance	0	9	0	3	1988	P
CN-13S	Shuttle Navigation Via Geosync. Satellite	0	4	0	3	1988	P
CN-51A	Intelsat	3	464	0	3	1985	S
CN-53A	US Domsat B	3	464	0	3	1985	S
CN-54A	Disaster Warning Satellite	1	275	0	3	1985	S
CN-55A	Traffic Management Satellite	0	669	0	3	1985	S
CN-58A	US Domsat C	1	492	0	3	1985	S
CN-59A	Comm R&D/Prototype Satellite	2	1,907	2	3	1985	S
CN-60A	Foreign Comm. Satellite B	0	426	0	3	1985	S
CO-01	Advanced Res/Pollution Observation	30	4,460	12	2	1985	P
CO-06	UN Trace Observation	4	7,069	3	2	1990	P
CO-10	Atmospheric Temp Sounder	43	1,500	10	2	2000	N
CO-11	Atmospheric Temp Sounder	4	105	5	2	1990	P
CO-2	Forest Fire Detection	25	10,500	2	4	1990	S
CO-8	Border Surveillance	3	2,650	12	4	1990	S
CO-9	Coastal Passive Radar	110	27,500	2	4	1995	S
CS-10	Vehicular Speed Control	10	2,000	0	4	1990	S
CS-13	Inexpensive Navigation	1	275	10	4	1990	S
CS-6	City Night Illuminator	150	30,000	0	4	1990	S
C-01	IR Astronomy	31	4,500	1	18	1985	N
C-02	UV Astronomy	24	1,100	1	27	1985	N
C-03	Solar Observations	15	1,000	1	26	1988	N
C-04	Space Sciences 1	17	2,700	2	29	1986	P
C-05	Space Sciences 2	16	2,200	2	20	1986	P
C-06	AMPS/Earth Sciences	24	1,900	2	27	1986	P
C-07	Space Technology	26	2,300	10	22	1986	N
C-08	Cloud Physics/Technology	15	2,000	1	17	1987	N
C-09	Earth Sciences 1	25	6,100	2	17	1987	P

CO-9	Coastal Passive Radar	110	27,500	2	4	1995	S
CS-10	Vehicular Speed Control	10	2,000	0	4	1990	S
CS-13	Inexpensive Navigation	1	275	10	4	1990	S
CS-6	City Night Illuminator	150	30,000	0	4	1990	S
C-01	IR Astronomy	31	4,500	1	18	1985	N
C-02	UV Astronomy	24	1,100	1	27	1985	N
C-03	Solar Observations	15	1,000	1	26	1988	N
C-04	Space Sciences 1	17	2,700	2	29	1986	P
C-05	Space Sciences 2	16	2,200	2	20	1986	P
C-06	AMPS/Earth Sciences	24	1,900	2	27	1986	P
C-07	Space Technology	26	2,300	10	22	1986	N
C-08	Cloud Physics/Technology	15	2,000	1	17	1987	N
C-09	Earth Sciences 1	25	6,100	2	17	1987	P
C-10	Earth Sciences 2	26	6,000	2	8	1987	P
C-11	High Energy Astronomy/Technology	20	1,200	1	16	1987	N
C-12	Life Sciences/Material Tech. 1	100	13,300	10	20	1988	N
C-13	Life Sciences/Material Tech. 2	81	10,600	6	20	1987	N
C-14	IR/UV Astronomy	45	2,000	2	11	1988	P
C-15	UV Astronomy-Advanced	24	1,000	1	11	1989	P
C-16	Cosmic Ray Laboratory	50	5,600	1	16	1991	N
C-17	Long Duration Life Science Laboratory	39	2,600	8	27	1991	N
C-18	Advanced Technology	8	1,600	2	10	1988	P
C-19	Space Manufacturing	7	200	5	12	1990	P
EO-07A	Advanced Sync. Metsat.	2	2,643	0	3	1987	S
EO-08A	Earth Observations Satellite	7	2,721	0	1	1986	P
EO-09A	Synchronous Earth Observation Satellite	3	2,643	0	3	1987	S
EO-10A	Applications Explorer	0	22	0	1	1985	P
EO-12A	Tiros O Satellite	4	990	0	1	1987	P
EO-56A	Environmental Monitors Satellite	4	915	0	1	1985	P
EO-57A	Foreign Sync. Metsat.	0	308	0	3	1986	S
EO-58A	Geosync. Operational Metsat.	0	308	0	3	1988	S
EO-59A	Geosync. Earth Resources Satellite	3	508	0	3	1988	S
EO-61A	Earth Resources Operational Satellite	1	194	0	1	1985	P
EO-62A	Foreign Sync. Earth Observation Satellite	3	508	0	3	1988	S
HE-01A	Large X-ray Telescope	26	9,186	1	24	1985	N
HE-03R	X-ray Survey Revisit	9	11	1	24	1985	N
HE-07A	Small High Energy Satellite	1	242	0	4	1985	N
HE-08A	Large High Energy Observatory A	19	2,997	0	24	1988	N
HE-10A	Large High Energy Observatory C	11	1,005	0	24	1986	N
HE-11S	X-ray Angular Structure	13	15	0	10	1985	N
HE-12A	Cosmic Ray Laboratory	22	1,560	1	24	1986	N
HE-12S	High-Inclination Cosmic Ray Survey	11	60	0	6	1985	N
HE-13S	X-ray/Gamma Ray Pallet	11	15	0	24	1985	N
HE-15S	Magnetic Spectrometer	9	15	0	24	1988	N
HE-16S	High Energy Gamma Ray Survey	13	15	0	1	1987	N
HE-17S	High Energy Cosmic Ray Study	4	15	0	2	1985	N
HE-18S	Gamma Ray Photometric Studies	14	15	0	19	1985	N
HE-20S	High Resolution X-ray Telescope	9	24	0	12	1985	N
LS-02A	Biomedical Experiment Satellite	4	1,068	0	4	1985	N
MO-20	Synchronous Meteorological Satellite	3	2,500	1	4	1986	S
OP-03A	Mini-Lageos	0	2	1	1	1985	N
OP-05A	Vector Magnetometer Satellite	0	190	0	1	1985	P
OP-06A	Magnetic Field Monitor Satellite	0	60	0	1	1986	N
SO-3A	Solar Fine Pointing Payload	6	26	1	40	1986	N
SO-11S	Solar Maximum Mission	1	259	1	3	1985	N
ST-01A	Long Duration Exposure Facility	8	4,745	0	4	1986	N
ST-07S	Neutral Beam Physics	0	1	0	4	1985	N
ST-13S	Wake Shield Investigations	1	75	1	1	1985	N

*Payload Codes (Source): AP-AMPS (SSPDA), AS-Astronomy (SSPDA), CC-Civilian Communications (Aerospace), CN-Communications/Navigation (SSPDA), CO-Civilian (Aerospace), CS-Civilian Service (Aerospace), C-Combined (MOSC), EO-Earth Observations, HE- High Energy Astrophysics (SSPDA), LS-Life Science (SSPDA), MO-Military Observations (Aerospace), OP-Earth and Ocean Physics (SSPDA), SO-Solar Observations (SSPDA), ST-Space Technology (SSPDA).

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of these payloads and their descriptive characteristics, as listed in Table 4-1, are (1) the 19 MOSC payload combinations (developed in the baseline study), (2) the 19 of the 28 initiatives (payloads) described in the Future National Needs Study (Aerospace Corporation), and (3) the remainder of the sortie and automated payloads described in the SSPDA Level A and B, 1974 version, not included in (1) above, but shown as candidates for flights within the 1985-to-2000 schedule period.

The Aerospace study describes 26 initiatives or payloads at a specificity of detail roughly equivalent in technical content to the SSPDA Level A descriptions for automated payloads. A listing of these initiatives/payloads is shown in Table 4-2. Of the 28 payloads described 19 were included as MOF candidates. Those excluded were eight payloads where specialized orbital conditions were required. The other initiative identified in the Aerospace Study is CS-3 Energy Generation, which is equivalent to the 25 million pound version of the SSPS as described in Paragraph 3.1.3 of this report. CS-3 represents a payload concept disproportionate in scale to the other 99 payloads. Therefore this initiative was considered a mission requirement rather than a specific payload.

The entries in first and second columns of Table 4-1 represent the payload identification code and descriptor as found in the source descriptions. The third column is an estimated weight of the payload in kilopounds while the fourth column lists the volumetric requirements in cubic feet. The fifth column is an estimate of power requirements in terms of kilowatts. All values found in these three numeric columns have been rounded off to the nearest unit. The next column (6) represents the number of man-hours per day in orbit that the payload requires from the payload specialist to perform duties such as payload assembly, deployment, and operation. The desired mission initiation date is included along with the desired earth orbital parameters (N = 28.5° low altitude, P = 90° low altitude, S = geostationary synchronous).

An examination of the functional and operational features of each of the 99 payloads indicated that it was possible to assign each payload to a mission role in one or more of the MOF major mission activities. Figure 4-3 describes for each mission activity area, the payloads in the collection of the

Table 4-2

AEROSPACE FUTURE NATIONAL NEED INITIATIVES

Advanced resources/pollution obs	CO-1	P
Forest fire detection	CO-2	G
U.N. truce observation	CO-6	P
Nuclear fuel location	CO-7	X
Border surveillance	CO-8	G
Coastal passive radar	CO-9	G
Astronomical telescope	CO-10	N
Atmospheric temperature sounder	CO-11	P
Global search and rescue	CC-1	G
Urban/police wrist radio	CC-2	G
Disaster control	CC-3	G
Electronic mail transmission	CC-4	G
Transportation services	CC-5	X
Voting/polling	CC-7	G
National information services	CC-8	G
Personal communications	CC-9	G
Diplomatic hotlines	CC-10	G
Nuclear energy plant	CS-1	X
Energy generation plant	CS-2	X
Energy generation (glaser)	CS-3	S
Nuclear waste disposal	CS-4	X
Aircraft beam powering	CS-5	X
City night illuminator	CS-6	G
Vehicular speed control	CS-10	G
Space debris sweeper	CS-11	X
Ozone layer replenishment	CS-12	X
Inexpensive navigation	CS-13	G
Synchronous meteorological satellite	MO-20	G

Legend: P = polar orbit, G = geosynchronous orbit, N = nominal (28-1/2°) orbit,
S = solar power station - considered as a mission requirement rather than a payload
X = special orbit required or other consideration - not included in preliminary mission model

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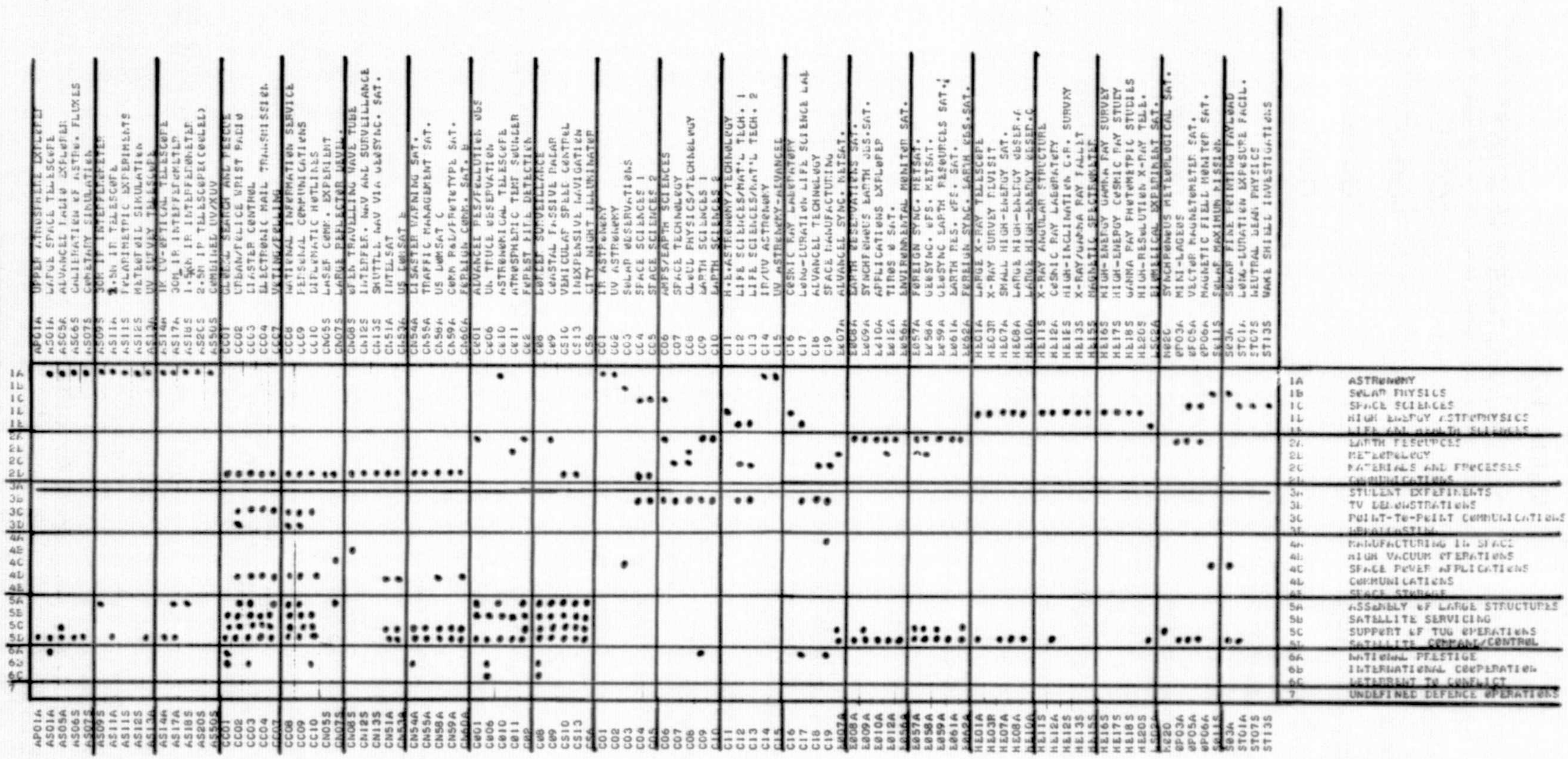

Figure 4-3. Correlation of MOF Utilization Areas to 99 Payloads

99 that might be assigned to that category. The distribution of these assignments is shown in Figure 4-4 along with the rank order of interest in the activity areas, as based upon the numbers of payloads which can be categorized into each area.

4.2 NEAR-TERM MISSIONS IDENTIFIED

Flight schedules for the initial time period of 1985-1991 derived from the requirements delineated in the SSPDA, the NASA traffic model (October 1973) and the Aerospace Study have been accumulated and are presented in Figures 4-5, 4-6, and 4-7 These three schedules represent the point of departure from which the MOF mission model was derived. Figure 4-5 presents the payloads scheduled for flight between 1985 and the year 1991 in low inclination (28.5 degrees) earth orbit. For the 47 payloads shown, 113 flights are required to fulfill the mission objectives presently defined for these payloads. On this schedule and the others shown in Figures 4-6 and 4-7, a solid dot represents the desired year of flight and the adjacent letter (A, D, or S) represents the class of manned mission involvement.

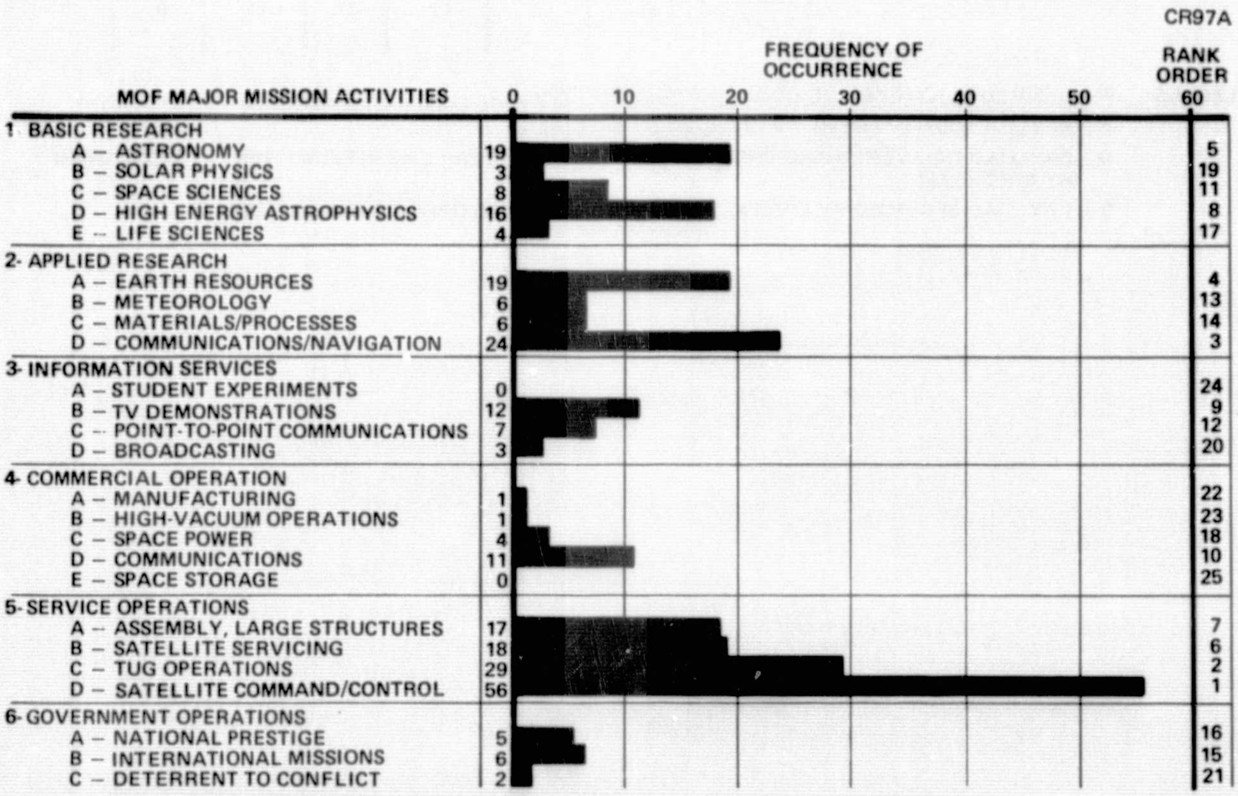

Figure 4-4. Distribution of 99 Payload Assignments

CR123

PAYLOAD	CODE	1985	1986	1987	1988	1989	1990	1991
ADVANCED RES/POLLUTION OBS	C0-1	● D			● S			● S
LASER COMM EXPERIMENT	CN-5S	● A		● A	● A	● A		
LARGE REFLECTOR DEVEL	CN-7S	● A	● A	● A				● A
APPLICATIONS EXPLORER	E0-10A	● D	● D	● D	● D	● D	● D	● D
ENVIRONMENTAL MONITOR SATELLITE	EO-56A	● D	● D	● D	● D		● D	● D
EARTH RES OBS SATELLITE	EO-61A	● D	● D	● D	● D	● D	● D	● D
VECTOR MAGNETOMETER SATELLITE	OP-5A	● D	● D	● D	● D	● D	● D	
UPPER ATMOSPHERE EXPLORER	AP-1A	● D				● D		
SPACE SCIENCES I	C4		● A	● A				
SPACE SCIENCES 2	C5		● A		● A			
AMPS/EARTH SCIENCES	C6		●● A					
EARTH OBSERVATIONS SATELLITE	EO-8A		● D	● D		● D		● D
EARTH SCIENCES 1	C9			●● A				
EARTH SCIENCES 2	C10			●● A				
TIROS O SATELLITE	EO-12A			● D				
IR/UV ASTRONOMY	C14				● A	● A		
ADVANCED TECHNOLOGY	C18				● A			
INTER NAV AND SURVEILLANCE	CN-12S				● A	● A	● A	
SHUTTLE NAV VIA GEOSYNC SAT.	CN-13S				● A	● A	● A	
UV ASTRONOMY – ADVANCED	C15					●● A		
SPACE MANUFACTURING	C19						● A	● A
ATMOSPHERIC TEMP SOUNDER	CO-11						● D	
UN TRUCE OBSERVATION	CO-6						● D	
	FLIGHT YEAR	8	10	13	11	11	9	7

LEGEND: ● – DESIRED FLIGHT PERIOD CODED BY MISSION TYPE

A – PAYLOAD CONTINUOUSLY ATTENDED BY SPECIALIST

D – PAYLOAD DELIVERED AND CHECKED OUT BY CREW AS WELL AS INTERMITTENTLY MONITORED BY SPECIALIST

S – PAYLOAD SERVICED BY SPECIALIST AND RETURNED TO OPERATIONAL STATUS.

Figure 4-5. Payload Flight Schedule – 28.5° Facility

CR123

PAYLOAD	CODE	1985	1986	1987	1988	1989	1990	1991
IR ASTRONOMY	C1	● A	●					
UV ASTRONOMY	C2	●● A						
CALIBRATION OF ASTRO FLUXES	AS-6S	● A	● A					
COMETARY SIMULATION	AS-7S	● A	● A					
30M IR INTERFEROMETER	AS-9S	● A						
POLARIMETRIC EXPERIMENTS	AS-115		● A					
METEROID SIMULATION	AS-12S	● A	● A					
1.5-KM IR INTERFEROMETER	AS-18S	● A	● A		● A		● A	·
X-RAY ANGULAR STRUCTURE	HE-11S	● A	● A		● A		● A	
HIGH-INCLINATION C.R. SURVEY	HE-12S	● A	● A			● A		
X-RAY/GAMMA RAY PALLET	HE-13S	● A	● A				● A	
HIGH-ENERGY COSMIC RAY STUDY	HE-17S	● A		● A		● A	● A	
GAMMA RAY PHOTOMETRIC STUDIES	HE-18S	● A		● A		● A		● A
HIGH-RESOLUTION X-RAY TELE	HE-20S		● A					
X-RAY SURVEY REVISIT	HE-3R	● A						
SOLAR FINE POINTING PAYLOAD	SO-11S	● A						
NEUTRAL BEAM PHYSICS	ST-7S	●●● A	● A					
WAKE SHIELD INVESTIGATIONS	ST-13S	●● A	●● A					
OPEN TRAVELING WAVE TUBE	CN-8S	● A	● A	● A				
LARGE X-RAY TELESCOPE	HE-1A	● D						
LARGE HIGH-ENERGY OBSER A	HE-8A	● D						
MINI-LAGEOS	OP-3A	●● D	● D					
BIOMEDICAL EXPERIMENT SATELLITE	LS-2A	●● D	●● D	●● D	●● D	●● D	●● D	●● D
SPACE TECHNOLOGY	C7		● A					·
COMBINED UV/XUV	AS-50S		● A		● A		● A	
UV SURVEY TELESCOPE	AS-13A		● D	● D				
LARGE HIGH-ENERGY OBSER C	HE-10A		● D					
COSMIC RAY LABORATORY	HE-12A		● D					·
SOLAR MAXIMUM MISSION	SO-3A		● D		● D		● D	
MAGNETIC FIELD MONITOR SATELLITE	OP-6A		● D				● D	
LONG-DURATION EXPOSURE FACIL	ST-1A		● D		● D		● D	
H.E. ASTRONOMY/TECHNOLOGY	C11			● A	● A			
LIFE SCIENCES/MATERIAL TECH 2	C13			● A			● A	
HIGH ENERGY GAMMA RAY SURVEY	HE-16S			● A				
1.5M IR TELESCOPE	AS-11A			● D			● D	
IM UV-OPTICAL TELESCOPE	AS-14A			● D			● D	·
30M IR INTERFEROMETER	AS-17A			● D		● D		
SOLAR OBSERVATIONS	C3				● A	● A		● A
LIFE SCIENCES/MATERIAL TECH 1	C12			● A	●	● A		● A
MAGNETIC SPECTROMETER	HE-15S				● A			
LARGE SPACE TELESCOPE	AS-1A				● D			
SMALL HIGH-ENERGY SATELLITE	HE-7A				● D	● D	● D	● D
2.5M IR TELESCOPE (COOLED)	AS-20S					● A	● A	● A
COSMIC RAY LABORATORY	C16							● A
LONG-DURATION LIFE SCIENCE LAB	C17							● A
ASTRONOMICAL TELESCOPE	CO-10	NOT SCHEDULED UNTIL 2000						
CLOUD PHYSICS/TECHNOLOGY	C8					● A		·
	FLIGHT YEAR	27	25	13	13	11	15	9

LEGEND: ● – DESIRED FLIGHT PERIOD CODED BY MISSION TYPE
A – PAYLOAD CONTINUOUSLY ATTENDED BY SPECIALIST
D – PAYLOAD DELIVERED AND CHECKED OUT BY CREW AS WELL AS INTERMITTENTLY MONITORED BY SPECIALIST
S – PAYLOAD SERVICED BY SPECIALIST AND RETURNED TO OPERATIONAL STATUS

Figure 4-6. Payload Flight Schedule – Polar Facility

CR123

PAYLOAD	CODE	1985	1986	1987	1988	1989	1990	1991
GLOBAL SEARCH AND RESCUE	CC1	● D			● S			● S
DIPLOMATIC HOTLINES	CC-10	● D			● S			● S
ADVANCED RADIO EXPLORER	AS-5A	● D		● D				
GEOSYNC OPS METSAT	EO-58A	● D		● D	● D	● D		● D
INTELSAT	CN-51A	●● D	●● D			●● D	●●● D	●● D
US DOMSAT B	CN-53A	● D	●● D	●● D	●●● D	●● D	●● D	●
DISASTER WARNING SATELLITE	CN-54A	● D					● D	
TRAFFIC MANAGEMENT SATELLITE	CN-55A		● D		● D		● D	
US DOMSAT C	CN-58A				●●● D			
COMM R&D/PROTOTYPE SATELLITE	CN-59A	● D			● D		● D	
FOREIGN COMM SATELLITE B	CN-60A	● D	● D	● D	● D	● D	● D	● D
SYNCHRONOUS METEOROLOGICAL SAT.	MO-20	● D			● S			● S
FOREIGN SYNC METSAT	EO-57A		●		●		● D	
ADVANCED SYNC METSAT	EO-7A			● D				
SYNCHRONOUS EARTH OBS SAT.	EO-9A			●● D		●● D		●● D
GEOSYNC EARTH RESOURCES SAT.	EO-59A				●● D		● D	● D
FOREIGN SYNC EARTH OBS SAT.	EO-62A				● D	●● D		● D
FOREST FIRE DETECTION	CO-2						● D	
BORDER SURVEILLANCE	CO-8						● D	
URBAN/POLICE WRIST RADIO	CC-2						● D	
DISASTER CONTROL	CC-3						● D	
ELECTRONIC MAIL TRANSMISSION	CC-4						● D	
VOTING/POLLING	CC-7						● D	
NATIONAL INFORMATION SERVICE	CC-8						● D	
PERSONAL COMMUNICATIONS	CC-9						● D	
CITY NIGHT ILLUMINATOR	CS-6						● D	
VEHICULAR SPEED CONTROL	CS-10						● D	
INEXPENSIVE NAVIGATION	CS-13						● D	
COASTAL PASSIVE RADAR	CO-9	NOT SCHEDULED UNTIL 1993						
	FLIGHTS YEAR	11	7	8	17	10	22	12

LEGEND:
- ● – DESIRED FLIGHT PERIOD CODED BY MISSION TYPE
- A – PAYLOAD CONTINUOUSLY ATTENDED BY SPECIALIST
- D – PAYLOAD DELIVERED AND CHECKED OUT BY CREW AS WELL AS INTERMITTENTLY MONITORED BY SPECIALIST
- S – PAYLOAD SERVICED BY SPECIALIST AND RETURNED TO OPERATIONAL STATUS

Figure 4-7. Payload Flight Schedule – Geosynchronous Facility

An A-class mission constitutes a payload where the manned involvement is required on a continuous or near-continuous basis. This includes the 19 MOSC combinations and all of the SSPDA sortie payloads. The letter D designates a payload where initially the payload (or spacecraft) would be deployed, assembled, and checked out under manned control and then relegated to an automated mode of operation. The third class as shown by the letter S is a mission where a payload (or satellite) would be retrieved for servicing by the crew and then returned to automated service for an extended life period.

Figure 4-6 presents the 23 payloads scheduled for polar orbit. These 23 payloads would require 60 flights to complete the stated mission objectives. These payload flights are not be be confused with an STS flight, as a single STS flight could deliver several payloads to the MOF. On the other hand, a specific payload mission might require several payload flights to accomplish the space activities required by such an individual segment of the overall mission. Similarly, Figure 4-7 indicates the geostationary orbit payload schedule of 29 payloads spread across 87 payload flights.

4.3 FAR TERM MISSIONS IDENTIFIED

Among the potential users contacted, it was unanimously agreed that a permanent free-flying manned orbital facility represents a desirable and attractive objective to pursue after the Shuttle becomes operational. Secondly, it was generally agreed by all persons contacted that new uses and new payloads beyond those being considered in the NASA mission model will emerge as experience is gained in early Shuttle missions and as future needs are clarified.

Figure 4-8 presents a comparison of the rank orders of the major mission areas in terms of the future mission requirements (needs identified by potential users) and in terms of near term requirements (as based on the 99 payload assignments described previously.) Analysis of these data suggest possible trends in changing mission emphasis. A high ranking in the needs column for example would suggest a potentially high future interest in a

MOF MAJOR MISSION AREAS	RANK ORDER NEEDS	RANK ORDER PAYLOADS	FUTURE REQUIREMENTS REMARKS
1 – BASIC RESEARCH			
A – ASTRONOMY	10	5	CONTINUING PROGRAM, ADD LARGE APERTURE INSTRUMENTS
B – SOLAR PHYSICS	9	19	CHANGING DEMANDS COINCIDENT WITH SOLAR ACTIVE PERIODS
C – SPACE SCIENCES	14	11	EMPHASIS ON UNMANNED PAYLOADS
D – HIGH ENERGY ASTROPHYSICS	16	8	
E – LIFE SCIENCES	11	17	INCREASING EMPHASIS WITH EXTENDED CAPABILITIES
2 – APPLIED RESEARCH			
A – EARTH RESOURCES √	1	4	CONTINUING TOP CONTENDER – HIGH VALUE MISSION
B – METEOROLOGY √	2	13	INCREASE IN REQUIREMENTS FOR MANNED OBSERVATORY – HIGH VALUE MISSION
C – MATERIALS/PROCESSES	12	14	CONTINUING INTEREST
D – COMMUNICATIONS/NAVIGATION	15	3	EMPHASIS ON UNMANNED PAYLOADS
3 – INFORMATION SERVICES			
A – STUDENT EXPERIMENTS	19	24	FURTHER DEFINITION REQUIRED
B – TV DEMONSTRATIONS	22	9	CHANGING INTEREST
C – POINT-TO-POINT COMMUNICATIONS √	13	12	POTENTIAL HIGH VALUE MISSION
D – BROADCASTING	20	20	FURTHER DEFINITION REQUIRED
4 – COMMERCIAL OPERATIONS			
A – MANUFACTURING √	7	22	HIGH VALUE MISSION
B – HIGH-VACUUM OPERATIONS	25	23	LOW INTEREST – FURTHER DEFINITION REQUIRED
C – SPACE POWER	17	18	FURTHER DEFINITION OF SPACE STATION ROLE REQUIRED
D – COMMUNICATIONS √	8	10	HIGH VALUE MISSION
E – SPACE STORAGE	23	25	LOW INTEREST FOR SPACE STATION
5 – SERVICE OPERATIONS			
A – ASSEMBLY, LARGE STRUCTURES √	4	7	HIGH VALUE MISSIONS
B – SATELLITE SERVICING √	3	6	
C – TUG OPERATIONS	24	2	FURTHER DEFINITION REQUIRED
D – SATELLITE COMMAND/CONTROL	18	1	CONCEPT REQUIRES DEFINITION
6 – GOVERNMENT OPERATIONS			
A – NATIONAL PRESTIGE √	6	16	HIGH VALUE MISSIONS FOR SPACE STATION
B – INTERNATIONAL MISSION √	5	15	
C – DETERRENT TO CONFLICT	21	21	FURTHER DEFINITION REQUIRED

√ – HIGH VALUE MISSIONS

Figure 4-8. Combined: User Needs/Payloads

specific mission activity area. Likewise a high ranking in the payloads ranking would suggest a strong emphasis for near-term missions. A high ranking in both columns would suggest a strong continuing interest. The top nine out of 25 mission areas in terms of near term and long term interest have been identified on the chart as potentially high value missions. Qualifying remarks for each area are also included.

Further exploration of the far-term mission requirements reveals the following.

A. An emerging awareness has been noted of the need for scientific and technical projects to be related to, and supportive of, the solutions of the most pressing problems facing mankind. To this end, it would be important in the future to concentrate emphasis on the transition phase occurring as the research and development activities achieve their goals and as operational capabilities are defined and developed. Space applications in the areas of earth

observations, meteorology, and materials processing in space are among the more important research and development fields which are candidates for the transition-to-users phase.

B. Solicitation of new applications must be a continuing and directed effort. Experience obtained with the initial missions of the Orbiter-Spacelab will lead to a second generation of applications and operations requiring more sophisticated missions and facilities. Many of the payloads flown in the earlier time frames (i. e., 1980 to 1985 and 1985 to 1990) will prove feasibility and will establish the most promising approaches to instrumentation alternatives. The operational space activities will become more productively intense as the methods and mechanisms become established.

C. Manned facilities in geostationary orbit can be especially useful in selected areas of earth observations and in the assembly of large space structures. This new utilization of manned space will require the definition of new payloads to take advantage of emerging opportunities. New concepts for geosynchronous payloads which include cycling through an MOF to take advantage of servicing possibilities, updating, changeout of payload elements and the like will be prime candidates for definition.

D. New interfaces between currently defined automated payloads and MOF need to be considered. Past experience has shown that for an automated payload about two-thirds the cost (and weight) is devoted to the carrier spacecraft. By providing a common base, MOF offers the advantage of reducing the spacecraft content of the automated payloads. The degree is yet to be defined. The savings potential, however, is significant.

When the list of payloads that comprise the schedules shown in Figures 4-3 and 4-4 are examined in light of the research or applications objectives involved, certain patterns of commonality are observed. For example, for the 28.5° facility there are 16 payloads concerned with astronomy. In many cases individual payloads are outfitted with instruments with nearly identical performance criteria with the differences being in the specific design approaches taken in the mechanization of the apparatus. For example, when descriptions as found in the SSPDA of the 1.5m IR telescope (AS-11A) and the

1.5m IR telescope (AS-01A), which is a component of the MOSC Payload Combination C-1, are compared, the two basic instruments appear to be identical.

It can be expected that during the first five years of Spacelab/sortie payload operations several different instrument approaches will be tried. In fact, these first years will have as one of their objectives trials in space to rule out approaches that are less effective than their competitors. While at this stage of planning one can merely speculate on the outcome of the space competition insofar as predicting which payload will ultimately win out over its rivals, it is not without reason to predict that by the year 1990 the competition in each major discipline area will have arrived at an optimal payload approach.

The following scenarios are presented as reasonable lines of endeavor that the MOF facilities might support in the 1991 -to-2000 time period.

Earth Resources

The late 1970's and early 1980's will storehouse a tremendous quantity of data. The ground demand will only slightly tap the stockpile and the requirements for more automated satellite data will diminish leaving only the requirement in the MOF era for specialized, unique data which can be collected with the earth observation facilities.

Meteorological Satellites

The GARP[11] system using automated spacecraft (four LEO, two polar) will provide the data inputs to an accurate (95 percent) long-range (two weeks) forecast system with tremendous social and economic importance, provided that the ground processing problem can be solved. Manned observatories will prove a valuable adjunct to the automated system particularly for short-lived, highly destructive phenomena plus weather modification procedures.

(11) Report of the Study Conference on the Global Atmospheric Research Programme (GARP), ICSU/IUGG, Committee on Atmospheric Sciences, COSPAR, and World Meteorological Organization, July 1967.

Astronomy

After the multispectral instruments flown in the early Shuttle period are evaluated, it can be anticipated that select instruments will be favored for future work. Assuming that the large space telescope will be developed, the MOF assigned instruments need not to be as powerful as the LST. Instead they should be more flexible and, with manned assistance, reconfigurable to a wide variety of special demands from the space astronomy community. The radio telescope, assembled in space and working in the ground-forbidden regions of the spectrum, will assume major scientific importance. Also very long baseline interferometry will be a significant new source of data to the scientific community.

Zero-g Studies (Space Processing, Cloud Chamber, Life Sciences, Technology)

The reduced gravity environment is a unique property that the orbital station has to offer investigators and users of the MOF. In this environment both the role of gravity in processes can be isolated and understood (important to the life sciences) as well as the effects of the microgravity on materials and processes to eliminate undesirable conditions as found in terrestrial laboratories.

This area has a very large growth potential, especially for the manned station. Early Spacelab flights can be expected to verify the importance of the area and provide direction to the most profitable and exciting areas.

Communications/Navigation

In the beginning the relatively small/low-power elements of the communication satellite network were placed in space while the ground terminals were immense, high-power, large, high-gain devices. This pattern was indicative of the limited lifting capability of launch vehicles to deliver payloads to geostationary orbital altitudes. As a consequence the ground elements were few in number and characteristically very expensive. Because this scheme interfaced with existing ground land-line and microwave circuits, the economies of the ground stations were not a predominant factor in the overall cost savings considering their few numbers. However, in the future when the utility of

space augmented communications systems needs to be made available to the emerging multitudes and in view of the increased capabilities to deliver payloads to synchronous altitudes, the logic of the relative power of the space-versus-ground elements needs to be reassessed. Key factors in this assessment need to include access to the solar input as a source of virtually unlimited power, possibilities for very large space structures, and the supportive role of MOF.

4.4 MOF UTILIZATION POTENTIAL

The payloads identified and scheduled for flights in the initial time period (1985-1991) could be assigned entirely to MOF-class facilities. On the other hand, the entire group of payloads could be assigned to individual STS and spacelab flights. Another possibility would be to selectively assign certain payloads to the MOF facilities and the others to either STS automated payload delivery flights or to spacelab flights. It is sufficient to say that the principle difference in the two assignment approaches lies in the number of STS launches required to support the MOF versus the non-MOF cases. Preliminary estimates are that the savings in STS flights for the MOF approach versus the non-MOF approaches are in the neighborhood of 200 launches.

Perhaps a more meaningful comparison can be made of the relative transportation costs to the user of one approach over the other. This comparison assumes that the cost or expense parameter is meaningful to the user, which in certain cases may not be the case. For example, for extremely costly payloads, the transportation expense may well be an insignificantly small fraction of the total. On the other hand, as an era of space industrialization is approached, all costs or expenses to be borne by the user will be of strong economic significance.

In examining ways of reducing the cost of space operations to potential users, one basis for comparison is the dollar cost per orbital manhour. Orbital manhour costs in turn can be expressed in terms of the transportation cost per available manhour. Table 4-3 shows a sample calculation for a seven-day sortie flight and a longer duration (90-day) manned orbital facility. It was assumed here than one orbiter mission flight costs $12.5 million. This

Table 4-3

SORTIE/MOF COMPARISON

	Sortie Only	MOF Only
Expense/flt ($ million)	$12.5	12.5
Payload specialists	4	4
Available hours/day/flight	12	8
Days/flight	7	88
Unscheduled work factor	1	6/7
Expense/man-hour, no learning	$37,202	$5,179
Expense/man-hour, with 85% learning (0.55 factor)	$37,202	$2,848

figure was divided by the number of working manhours available (the product of crew size, available hours/day, days of flight, and a factor for flights greater than seven days for rest or unscheduled activities) to derive the expense per manhour. Skylab experience suggests that an 85 percent learning curve can be assumed for longer duration missions to reflect the improvement in crew performance and operation as the crews acclimate to space. The factor is 0.55 for 7-day versus 88-day flight durations. Improved efficiency experienced can provide a further reduction in cost per manhour since the crew is accomplishing more work per unit time.

Figure 4-9 compares the relative orbital manpower transportation expense as a function of STS flight cost. The three curves shown on the figure represent the orbital manhour transportation cost for a Spacelab sortie flight, a MOF 90-day flight with no allowance for learning, and a MOF 90-day flight when the learning factor is considered. The substantially reduced manhour figures become attractive to potential new industrial users.

4.5 MISSION MODEL CONSTRUCTION

As a first step in the construction of the preliminary MOF mission model the payload flight schedules as shown in Figures 4-5, 4-6 and 4-7 were examined. The 19 payload combinations defined during the basic MOSC study, and as delineated on Table 4-1 were assigned to MOF. This assignment was made because it had been determined early in the basic study that the payloads represented by the 19 combinations favored or benefited directly from the extended capability available from MOF. In addition the 19 payloads identified

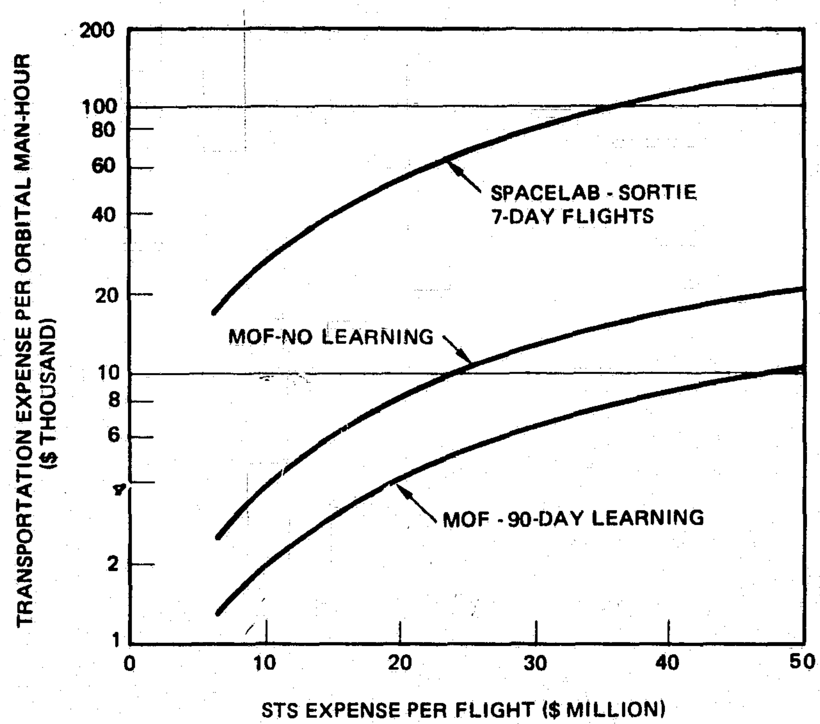

Figure 4-9. Orbital Manpower Expense

as initiatives in the Aerospace study were assigned to MOF. This assignment was made under the assumption that these payloads would also require the extended capabilities of the MOF. Evidence to this end can be seen by examining the building block and technology requirements for these 19 payloads as described in the Aerospace Study.

Other payloads were assigned to MOF missions when it was determined that they were sufficiently similar to a MOSC combination to warrant their inclusion as part of MOSC payload. For example the sortie payload SO-11S, Solar Fine Pointing Payload contains the same basic complement of instruments as SO-1S which is part of MOSC combination C-1. In addition certain other sortie payloads were assigned to a MOF mission when after one or more sortie flights, the work might just as well be accomplished by the MOF. For an example CN-5S, Laser communication experiment could be assigned to the MOSC combination C-4 after a sortie flight in 1985 and when the polar MOF become available in 1987.

After 1991 all payloads were assigned to MOF under the assumption that by this time frame the transition to Space Station would have been accomplished. The next section describes the details of the preliminary MOF mission model.

4.6 PRELIMINARY MOF MISSION MODEL

As stated previously, one of the desired products of the study was a representative model of the missions that the MOF concept could support. This model in turn could become a strawman for further studies and could be used as a baseline for evaluation of the utilization potential of a MOF. To this end, a mission model was synthesized and stated in terms of individual payloads selected to meet the goals and objectives set forth as recommendations for the manned missions of the 1985-to-2000 time frame.

The preliminary MOF mission model is summarized on Figure 4-10 and the groupings of payloads in terms of 28.5 degrees, polar, and geosynchronous orbits are summarized in Figures 4-11 and 4-16. The complementary sortie and automated payloads for each orbit are also presented for reference purposes.

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MISSION ACTIVITIES		CALENDAR YEAR 85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	2000
BASIC RESEARCH																	
ASTRONOMY	1-A	1	2		3	3	4	2	2	2	3	1	1	2	1	2	2
SOLAR PHYSICS	1-B	1			1	1		1	1	1	1	1					
SPACE SCIENCES	1-C			3	2	1	2	1	2	1	1	1					
HE ASTROPHYSICS	1-D			1	1	1	1	1	2	1							
LIFE SCIENCES	1-E	1	1	1	1	1	1	1	1	1	1						
APPLIED RESEARCH																	
EARTH RESOURCES	2-A			4	4	2	4	2	1	1	2	3	2	3	2	2	2
METEOROLOGY	2-B		1				2	1	2	2	2	2	2	2	2	2	2
MATERIALS AND PROCESSES	2-C	1	3	2	3	2	3	2	2	1	2	1	2	1	2	1	2
COMMUNICATIONS	2-D			3	2		2	3	3	2	2	3	2	2	2	2	2
INFORMATION SERVICES																	
STUDENT EXPERIMENTS	3-A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
TV DEMONSTRATIONS	3-B	1	3	6	6	3	7	5	5	3	4	3	2	2	3	2	3
POINT-TO-POINT COMMUNICATIONS	3-C						1	1	1	1	1	1	1	1	1	1	1
BROADCASTING	3-D							1	1	1	1	1	1	1	1	1	1
COMMERCIAL OPERATIONS																	
MANUFACTURING IN SPACE	4-A							1	1	1	1	1	1	1	1	1	1
HIGH VACUUM OPERATIONS	4-B	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
SPACE POWER APPLICATIONS	4-C			1	3	2		2	1	1	1	1			1	1	2
COMMUNICATIONS	4-D							1	2	2	2	2	2	2	2	2	2
SPACE STORAGE	4-E																
SERVICE OPERATIONS																	
ASSEMBLY OF LARGE STRUCTURES	5-A			1	2		1	1			1	1		1	1	1	2
SATELLITE SERVICING	5-B				1		3			3	2	2	2	2	1	3	2
SUPPORT OF TUG OPERATIONS	5-C																
COMMAND AND CONTROL	5-D			3	3	1	6	2	1	2	2	2	2	2	2	2	2
GOVERNMENT OPERATIONS																	
NATIONAL PRESTIGE	6-A				1	1	2	2	1	1	1	1	1	1		1	1
INTERNATIONAL COOPERATION	6-B						1			1			1			1	
DETERRENT TO CONFLICT	6-C						1			1			1			1	
DEFENSE OPERATIONS		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Figure 4-10. Preliminary MOF Mission Model

On Figure 4-10 the numerical entries represent when a particular payload is shown scheduled to support a mission activity. The dashes in this figure represent mission activities where the payload scheduling requires further study and definition. The schedules presented in Figures 4-11, 4-13 and 4-15 represent the payloads scheduled for MOF activities in 28. 5 degree, polar and geostationary orbits respectively. Figures 4-12, 4-14 and 4-15 represent the schedules for the sortie and automated payloads necessary to complement the MOF program so as to satisfy all of the identified mission requirements. Notes in the fields of the figures indicate a transition from an automated or sortie complementary flight to a MOF assigned activity. For example on Figure 4-14 the arrow pointing upward to the symbol "C4" under the 87 column and opposite the payload "LASER COMM EXPERIMENT – CN-5S" indicates that this payload would be assigned to a MOF flight in the year 1987. Carrying through on this example Figure 4-13 shows opposite the payload "SPACE SCIENCES 1-C-4" the notation "CN-5S" under the 87 column, indicating that an automated payload activity had been transferred to a MOF payload assignment.

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PAYLOADS ASSIGNED TO MOF		85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	2000
IR ASTRONOMY	C-1	●	●		●	AS-20S ●	AS-20S ●	AS-20S ●									
UV ASTRONOMY	C-2		AS-50S ●		AS-50S ●		AS-50S ●		●		●			●		●	●
SOLAR OBSERVATIONS	C-3	SO-11S ●			●	●		●	●	●	●	●					
HE ASTRONOMY/TECHNOLOGY	C-11			HE-16S ●	HE-16S ●	●	●	●									
SPACE TECHNOLOGY	C-7		●		SPACE POWER ●	●			●		●		●		●		
CLOUD PHYSICS/TECHNOLOGY	C-8		●		●		●										
LIFE SCIENCES/MATERIAL TECH 1	C-12	●	●	●		●											
LIFE SCIENCES/MATERIAL TECH 2	C-13				●		●										
LONG DURATION LIFE SCIENCE LAB	C-17							●	●	●	●						
COSMIC RAY LABORATORY	C-16							●	●								

Figure 4-11. 28.5 Deg Orbit MOF Payload Flight Schedule

CR97A

PAYLOAD		85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	2000
CALIBRATION OF ASTRO FLUXES	AS-6S	●	●														
COMETARY SIMULATION	AS-7A	●	●														
30M IR INTERFEROMETER	AS-9S	●															
POLARIMETRIC EXPERIMENTS	AS-11S		●														
METEOROID SIMULATION	AS-12S	●	●														
1.5 KM IR INTERFEROMETER	AS-18S	●	●		●		●										
X-RAY ANGULAR STRUCTURE	HE-11S	●	●		C11												
HIGH INCLINATION CR SURVEY	HE-12S	●	●		↓												
X-RAY/GAMMA RAY PALLET	HE-13S	●	●														
HIGH ENERGY COSMIC RAY STUDY	HE-17S	●			C11												
GAMMA RAY PHOTOMETRIC STUDIES	HE-18S	●			C11												
HIGH RESOLUTION X-RAY TELE	HE-20S		●		↓												
X-RAY SURVEY REVISIT	HE-3R	●															
NEUTRAL BEAM PHYSICS	ST-7S	●●●	●														
WAKE SHIELD INVESTIGATIONS	ST-13S	●●	●●														
OPEN TRAVELLING WAVE TUBE	CN-8S	●	●	●													
LARGE X-RAY TELESCOPE	HE-1A	●															
LARGE HIGH ENERGY OBSER A	HE-8A	●															
MINI-LAGEOS	OP-3A	●●	●														
BIOMEDICAL EXPERIMENT SAT	LS-2A	●●	●●	●●	●●	●●	●●	●●									
UV SURVEY TELESCOPE	AS-13A		●	●													
LARGE HIGH ENERGY OBSER C	HE-10A		●				●										
COSMIC RAY LABORATORY	HE-12A		●				●										
SOLAR MAXIMUM MISSION	SO-3A		●		●		●										
MAGNETIC FIELD MONITOR SATELLITE	OP-6A		●				●										
LONG DURATION EXPOSURE FACILITY	ST-1A		●		●		●										
1.5M IR TELESCOPE	AS-11A			●			●										
1M UV-OPTICAL TELESCOPE	AS-14A			●			●										
30M IR INTERFEROMETER	AS-17A			●		●											
LARGE SPACE TELESCOPE	AS-1A				●												
SMALL HIGH ENERGY SATELLITE	HE-7A				●	●	●	●									

LEGEND: ● SCHEDULED PAYLOAD ↓ FUNCTION ASSIGNED TO MOF PAYLOAD

Figure 4-12. 28.5 Deg Orbit Complementary Sortie and Automated Payloads

CR97A

PAYLOADS ASSIGNED TO MOF		85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	2000
SPACE SCIENCES 1	C-4			● CN-6S	● CN-6S		AP-1A		●			●			●		
SPACE SCIENCES 2	C-5			● OP-5A			● OP-5A										
AMPS/EARTH SCIENCES	C-6			●	●	●											
EARTH SCIENCES 1	C-9			● EO-56A	● EO-56A		● EO-56A	● EO-56A									
EARTH SCIENCES 2	C-10			● EO-61A	● EO-61A	● EO-61A	● EO-61A										
IR/UV ASTRONOMY	C-14				●	●				●	●	●	●	●	●	●	●
ADVANCED TECHNOLOGY	C-18			● CN-7S	●			● CN-7S									
UV ASTRONOMY – ADVANCED	C-15					●	●										
SPACE MANUFACTURING	C-19						●	●	●	●	●	●	●	●	●	●	●
ATMOSPHERIC TEMPERATURE SOUNDER	CO-11						●										
UN TRUCE OBSERVATION	CO-6						●			●			●			●	
ADVANCED RES/POLLUTION OBS	CO-1				●			●			●			●			●
SATELLITE SERVICING MISSIONS	NEW						● DEMONSTRATION			●		●		●		●	

Figure 4-13. Polar Orbit MOF Payload Flight Schedule

CR97A

PAYLOAD		85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	2000
LASER COMM EXPERIMENT	CN-5S	●		C4 ↑													
LARGE REFLECTOR DEVELOPMENT	CN-7S	●	●	C18 ↑													
INTERFER NAV AND SURVEILLANCE	CN-12S				●	●	●										
SHUTTLE NAVIGATION VIA GEOSYNC SAT	CN-13S				●	●	●										
EARTH OBSERVATIONS SATELLITE	EO-8A		●	●		●		●									
APPLICATIONS EXPLORER	EO-10A	●	●	●	●	●	●	●									
ENVIRONMENTAL MONITOR SATELLITE	EO-56A	●	●	C9 ↑													
EARTH RESOURCES OBS SATELLITE	EO-61A	●	●	C10 ↑													
VECTOR MAGNETOMETER SATELLITE	OP-5A	●	●	C5 ↑													
OPERATIONAL WEATHER AND EARTH OBSERVATIONS SATELLITES									●	●	●	●	●	●	●	●	●
UPPER ATMOSPHERE EXPLORER	AP-1A	●				C5 ↑											
TIROS 0 SATELLITE	EO-12A				●												

LEGEND: ● SCHEDULED PAYLOAD ↑ FUNCTION ASSIGNED TO MOF PAYLOAD

Figure 4-14. Polar Orbit Complementary Sortie and Automated Payloads

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PAYLOAD ASSIGNED TO MOF			85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	2000
FOREST FIRE DETECTION	CO-2	CLUSTER CONCEPT PAYLOADS						●			●			●			●	
BORDER SURVEILLANCE (1)	CO-8	CLUSTER CONCEPT PAYLOADS						●			●			●			●	
URBAN/POLICE WRIST RADIO (1)	CC-2	CLUSTER CONCEPT PAYLOADS						●			●			●			●	
DISASTER CONTROL	CC-3	CLUSTER CONCEPT PAYLOADS						●			●			●			●	
ELECTRONIC MAIL TRANSMISSION	CC-4	CLUSTER CONCEPT PAYLOADS						●			●			●			●	
VOTING/POLLING (1)	CC-7	CLUSTER CONCEPT PAYLOADS						●			●			●			●	
NATIONAL INFORMATION SERVICE (1)	CC-8	CLUSTER CONCEPT PAYLOADS						●			●			●			●	
PERSONAL COMMUNICATIONS (1)	CC-9	CLUSTER CONCEPT PAYLOADS						●			●			●			●	
CITY NIGHT ILLUMINATOR (1)	CS-6	CLUSTER CONCEPT PAYLOADS						●			●			●			●	
VEHICULAR SPEED CONTROL (1)	CS-10	CLUSTER CONCEPT PAYLOADS						●			●			●			●	
INEXPENSIVE NAVIGATION (1)	CS-13	CLUSTER CONCEPT PAYLOADS						●			●			●			●	
COASTAL PASSIVE RADAR (1)	CO-9	CLUSTER CONCEPT PAYLOADS											●					
GLOBAL SEARCH AND RESCUE	CC-1	CLUSTER CONCEPT PAYLOADS							●			●			●			●
DIPLOMATIC HOTLINES	CC-10	CLUSTER CONCEPT PAYLOADS							●			●			●			●
ASTRONOMY/AMPS FACILITY	NEW							●	●	●	●	●						
EARTH OBSERVATORY	NEW							●	●	●	●	●	●	●	●	●	●	●
SPACE POWER STATION (1)	NEW									●	●	●				●	●	●
SATELLITE SERVICING MISSIONS	NEW								●	●	●	●	●	●	●	●	●	●
SATELLITE COMMAND AND CONTROL MISSIONS (CLUSTER CONCEPT)	NEW						●	●	●	●	●	●	●	●	●	●	●	●

PROTOTYPE LARGE STATION

(1) – CANDIDATE FOR SPACE ASSEMBLY

Figure 4-15. Geosynchronous Orbit Payload Flight Schedule

PAYLOAD		85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	2000
ADVANCED RADIO EXPLORER	AS-5A	•		•	•												
GEOSYNCHRONOUS OPERATIONS METSAT	EO-58A	•		•	•	•		•									
INTELSAT	CN-51A	••	••			••	•••	••									
U.S. COMSAT B	CN-53A	•	••	••	•••	••	••	•									
DISASTER WARNING SATELLITE	CN-54A	•					•										
COMMERCIAL AUTOMATED METSATS, ERSATS AND COMSATS SERVICED ON ORBIT									•	•	•	•	•	•	•	•	•
TRAFFIC MANAGEMENT SATELLITE	CN-55A		•		•		•										
U.S. COMSAT C	CN-58A				•••												
COMM R&D/PROTOTYPE SATELLITE	CN-59A	•			•		•										
FOREIGN COMM SATELLITE B	CN-60A	•	•	•	•	•	•	•									
SYNCHRONOUS METEOROLOGICAL SATELLITE	MO-20	•			•			•									
FOREIGN SYNCHRONOUS METSAT	EO-57A		•		•		•		•	•	•	•	•	•	•	•	•
ADVANCED SYNCHRONOUS METSAT	EO-7A			•													
SYNCHRONOUS EARTH OBS SATELLITE	EO-9A			••		••		••									
GEOSYNC EARTH RESOURCES SATELLITE	EO-59A				••		•										
FOREIGN SYNC EARTH OBS SATELLITE	EO-62A				•	••		•									

Figure 4-16. Geosynchronous Orbit Complementary Automated Payloads

Section 5

FACILITY DESIGN AND OPERATIONAL IMPACTS AND IMPLICATIONS

The new users contacted were appraised of the design characteristics of the MOF, its modular configuration, and its salient features, and were presented copies of the User's Guide. One of the purposes of this exposure was to stimulate payload planners and potential MOF users to participate in the program, which is completely flexible. Thus, suggestions for payloads, design requirements, additions or alterations to features, and other changes could be entertained and encouraged. Their comments were recorded on questionnaires or by MDAC study team interviews.

A summary of these comments pertaining to the MOF baseline design and/or their recommended changes are shown in Table 5-1.

The geosynchronous MOF was felt, on the part of several of the individuals contacted during the study, to be a most attractive option. For the later mission time periods (1990 and beyond) the MOF mission model as described in the preceding section shows a dramatic increase in payload flights of more complex nature. This facility would serve both as an earth observatory and as a service station for payloads or clusters of payloads at geosynchronous altitude. For rendezvous with these payloads either the MOF or the payload to be serviced would be brought together by means of an intermediate phasing orbit. Figure 5-1 plots the velocity requirements to affect these maneuvers. Whether it is best to phase the MOF to the payload or vice versa is a point beyond the scope of this study. In any case, a MOF maneuvering capability is an additional feature to be considered.

When the comments cited above were reviewed it is apparent that there was a general consensus of the suitability of the now defined MOF baseline to accommodate the payload requirements of the future. The subject of detailed

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Table 5-1

MOF PAYLOAD SUPPORT SERVICES

Subsystem	Baseline Service Available	Comments
Electrical power	8,000 watts at utility outlets, auxiliary power available as required	For space manufacturing operations peak power up to 28 kW for 10 minutes duration and up to 18 kW for one hour duration is desirable. This payload requirement would dictate changes to the thermal control system to enable the subsystems to handle the thermal transients since during processing the work materials would need to be cooled to specific stabilized temperature. Dual heat exchange loops might be required considering the heat rejection temperatures of 2.500°C and higher.
Communications and data management	Real-time up and downlinks, onboard recording, CCTV, computer-serviced situation displays, wideband (60 mHz) two-way circuits to ground	Provisions for communications contingencies should be included where failures of electrical power and the onboard communications equipment might occur. Direct visual contact with payload and all other onboard operations is essential. Closed-circuit TV is a desirable adjunct, but not a substitute for direct line-of-sight observations. Periscopes are a possibility that should be examined.
Stabilization and control	Stellar-inertial, solar-inertial, and local-vertical orientations; horizon and stallar references	The safety aspects of control moment gyros was expressed. Some means of monitoring gyro performance as an advance warning of failure is required.
Atmosphere	Standard 15-psi atmosphere; temperature and humidity controlled; cooling air for equipment	A two-level atmospheric pressure control (15 and 10 psia) would be highly desirable. The lower level would reduce overboard losses and facilitate EVA operations.
Orbits	Nominal- and polar-inclination low orbits (200 nmi) for early operations; high-altitude earth orbits (4,000 nmi) and geostationary orbits during later missions	Particular interest was voiced about the attractiveness of geostationary orbits as a vantage point for a manned earth observatory. Some concern was expressed about the exposure of the crew to the radiation environment of this altitude. Longitude changes need to be considered.
Microgravity	Onboard null-gravity levels to 10^{-5} g for extended periods for payloads attached to the MOF; lower levels (10^{-6} to 10^{-7} g) available for free-flying modules and subsatellites	General satisfaction was voiced for the free-flyer concept as an isolation against disturbances introduced by the Orbiter.
Pointing	Stabilized platforms for sensor pointing and unrestricted viewing from orbit	A most desirable feature is an all-atitude pointing capability without restrictions as to orientation duration and/or orbital position.
Access to space environment	Space environment's vacuum, solar input, and freedom from contamination continuously available	New EVA suits and related equipment which feature improved mobility and dexterity with higher pressure are highly desirable
Crew support	Average of 32 man-hours per day available for payloads; EVA activities can be planned for six hours for two crewmen on four days out of each five-day period; special skills and payload-oriented expertise available	In addition to payload specialists an interest was voiced in a full time station operator so that station upkeep maintenance, correction of faults, and other related functions would not burden the payload specialists.

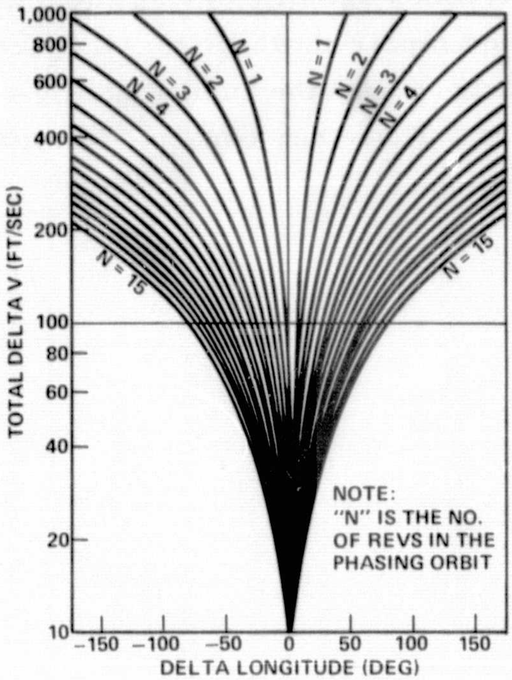

Figure 5-1. Velocity Requirement for Longitude Change in Equatorial Synchronous Orbit

payload module configurations to meet individual payload needs was given only cursory examination. The range and variety of individual payload modules as well as the complex subject of payload logistics remain as a study area yet to be explored. For example, the leaving of payloads in a dormant state for use during later flights was identified as a very attractive option in the views of the new users contacted. How this arrangement is best mechanized has not been studied.

While it was not the intent of the study to describe in detail the characteristics of new space station payloads, several concepts which are not currently described at the SSPDA level of detail were identified. Four advanced payload concepts can be highlighted as follows: (1) Payloads can be assembled and constructed in space using manned activities (Payloads in this class would include large aperture radio telescopes and high resolution earth sensors, large area solar energy collections, and large scale arrays of individual sensor elements and/or space power devices); (2) Payloads also could be

clustered on a common platform or controlled as satellites from an orbital command post; (3) New generation satellite design could take advantage of space-based maintenance and repair capabilities; (4) Space-based earth observatory can be constructed where the human intelligence serves as onboard sensors and data processors. These new concepts identified should be the subject of further consideration.

Section 6
CONCLUSIONS

In the User Analysis Supplementary Task, as described in this report, additional areas of utilization of manned orbital facilities were examined beyond those covered in the basic study. The purpose was twofold: (1) to provide a basis for constructing a preliminary mission model for extended duration manned space platforms to be operational in the 1985 to 2000 time period, and (2) to validate the baseline design concept as a viable and effective facility for meeting the anticipated needs of the future.

The following conclusions were reached by the study effort:

- A broad base of potential applications for a manned orbital facilities has been identified
- Preliminary mission model describes a transition from automated and sortie/spacelab flights as an interim step toward full scale space station activities in the 1990's
- Automated spacecraft in the space station period of the 1990's are described in the MOF mission model as new concepts taking advantage of on-orbit assembly, maintenance and repair, command and control and operating in the cluster or constellation mode
- The manned geosynchronous observatory is a future concept of keen interest to select users
- Space station supported payloads and systems can contribute to satisfaction of growing demands of the world's population
- The MOF concept is an important and pivotal building block in the exploration and utilization of space

The emerging billions of individuals must be considered candidate purchasers in the future markets for advanced technology. Their demands may include improved communications, more accurate weather forecasts, new space-age products, and many innovations yet to be discovered. For MOF, the market place is enormous, not today but in the foreseeable and not too distant future.

When the results of the individual user contacts and interviews conducted by the study team are reviewed, the general consenses can be summarized as follows:

A. Under the assumption that space activities for the 1985 time frame and beyond will be characterized in what could be termed a utilization phase (as contrasted to the exploration phase of the 1960's, 1970's, and early 1980's), the extended capabilities (free-flying, long-duration flights, and operational support of a broad range of manned space operations) offered by MOF are essential for the pursuit and continuance of a growing and international space effort.

B. After the initial Spacelab sortie flights planned for the early 1980's, a pattern of payload usage will emerge where the emphasis will be on direct benefits to mankind. These benefits will include direct personal services, availability of new and unique substances (produced in space with medical, economic, and new products implications), and extension of the scientific knowledge of nature and the universe.

C. The geosynchronous MOF options offer a significant and necessary advance in the utilization potential of manned space operations. Observatories, maintenance and repair stations, and large-scale assembly operations are examples of new services that a manned orbital facility at synchronous altitude can offer.

One further point warrants emphasis. As described in Section 3, there are strong demographic indicators of the future character, composition, and geographical distribution of world population. When the more detailed and advance population projections are examined, it is concluded that over the next 25 years the world population will double from its present level of about 3.5 billion. These projections show that the major portion of these emerging peoples inhabit the less developed regions of the world (i.e., Africa, Southeast Asia, et. al.). These people will inevitably be caught up in the revolution of rising expectations demanding the higher standards of life that technology can provide.

In summary, the baseline MOF design concept was confirmed as a viable and necessary step in the development and support of future orbital activities. A preliminary mission model was developed which described a transition from automated and short duration Spacelab flights to full scale space station activities in the 1990s. A manned geosynchronous observatory, in addition to facilities in 28. 5 and polar orbits, was found to be important in serving the interests of select users.

Section 7
RECOMMENDATIONS

This supplementary study covered a six-month performance period starting in April 1975. A broad approach was taken to contact a wide range of potential new users rather than probing any individual area in depth. During the course of the study there were areas uncovered that could prove to be promising avenues of research provided that sufficient time and resources were available. Several of these areas are discussed below.

The Skylab student project is an object lesson in the interest that can be generated on the part of new users in the space program. This project, proposed earlier by the National Academy of Science, was initiated and implemented during the year preceding the Skylab mission. Even though it covered a short response cycle, a great deal of interest was stimulated in students and teachers alike in space science and technology. In fact, the ultimate results of the project proved to be a bonanza insofar as significant student experiment success is taken as a measure. This is one area that is recommended for future MOF user analysis. Sufficient time (two or three years) should be allocated so that several cycles, as measured in terms of secondary school academic seasons are concerned, can be covered. It is expected that, when properly screened and evaluated, a good deal of new user interest and innovative requirements can result from a solicitation of student participation.

Another area that warrants further consideration is in the world-needs demographic approach. The present study was able to merely scratch the surface in considering projected needs and potential markets. One characteristic of demographic analysis that must also be taken into consideration is the long-term aspects of the analysis. Projections are typically made out to 100 years while the nearer term planning requirements resultant from world needs analysis range from 20 to 50 years.

Based upon the experience of the MOSC User Analysis activity, it is recommended that NASA establish a formal procedure for maintaining a continuing dialogue with potential users of the advanced manned space facilities and with "futurologists." In many areas future needs are not clearly defined and the incubation periods for defining problems and suggesting solutions may take several years. A continuing round of directed surveys can be a useful stimulant to identifying and documenting emerging needs and future trends. It is believed that unless this occurs as a formally directed effort however, it can lose much of its value to the NASA program planners.

Potential problems of the next century cannot wait for solutions until they become problems. It is necessary to anticipate problems and needs in advance and to develop desirable alternatives and solutions in timely fashion. For this reason demographic and econometric studies of future world markets should be included in mission planning studies. A planning model encompassing 20 years or more and updated yearly would be invaluable in program planning and in guiding the most cost effective utilization and investment of our limited national resources.

From the technical point of view manned assembly operations in space involving large structures remain a great unknown. Payload requirements projected for the 1990 and beyond time period show larger and more complex space elements. The automated deployment of these giant structures is by intuition a more costly and complex approach than one where men manually perform the required functions. In satisfaction of the new user needs which can be forecasted as attributable to these large structures, the technical advantages of manned space assembly operations should be evaluated.

The solicitation and identification of new uses should be addressed by NASA as a sustained and continuing effort and it is believed that sufficient time and budgetary allowances should be made to permit the pursuit of more promising leads as they are uncovered. It is recommended that future studies be structured along these continuing lines.

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Appendix A

COMMENTS OF INDIVIDUALS CONTACTED DURING THE STUDY

1. MDAC Contacts

During the course of the study, the following individuals were contacted by members of the MDAC study team. Salient points gained as a result of these interviews are summarized.

- Mr. SELWYN ENZER, Center for Futures Research, University of Southern California

Mr. Enzer is the Associate Director of the Center for Futures Research and an expert in the fields of world population projection and food demand trends. He was contacted as a source of information and for philosophic overview of the utility of a MOF to contribute toward satisfying the growing needs of the emerging populations of the world. Figure A-1*, as described by Mr. Enzer, shows three possible trends in world population growth reflecting three time-frames when the demographic statistical parameter, the net replacement ratio (NRR) reaches the zero growth level of 1.0. On the figure the plotted three trends coincide with the NRR dropping to 1.0 at present (immediate path), by the year 2000 (rapid path) and by the year 2040 (slow path). As can be seen from the figure a stabilized zero growth world population does not coincide with the period when the NRR reaches a value of 1.0 due to the decreased mortality rate being experienced worldwide. With increased longevity, even with zero growth, mankind is faced with a very significant increase in population throughout the remainder of this century and, if the slow path is experienced, the population of the world will not cease to grow until the end of the next century when world population could reach 15 billion persons. The critical issue that needs to be addressed is to identify how the MOF, and the utilization of space potential that it provides, can best serve the needs of the growing world population during the remainder of this century.

One example of an emerging problem area which needs solution is that of education and information exchange for large numbers of people. The demographic projections shown on Figures A-2 and A-3* depict the characteristic age distribution of the population of the USA and India as being typical of the growth anticipated for a developed country (USA) as contrasted to a developing country (India). Both projections show a substantial increase in the

*Derived from the projections of world population as forecasted by the eminent economist-demographer Dr. Tomas Frejka and reported in summary form in Population Bulletin — World Population Projections: Alternative Paths to Zero Growth, a publication of the Population Reference Bureau, Inc., Washington, D.C., 1974.

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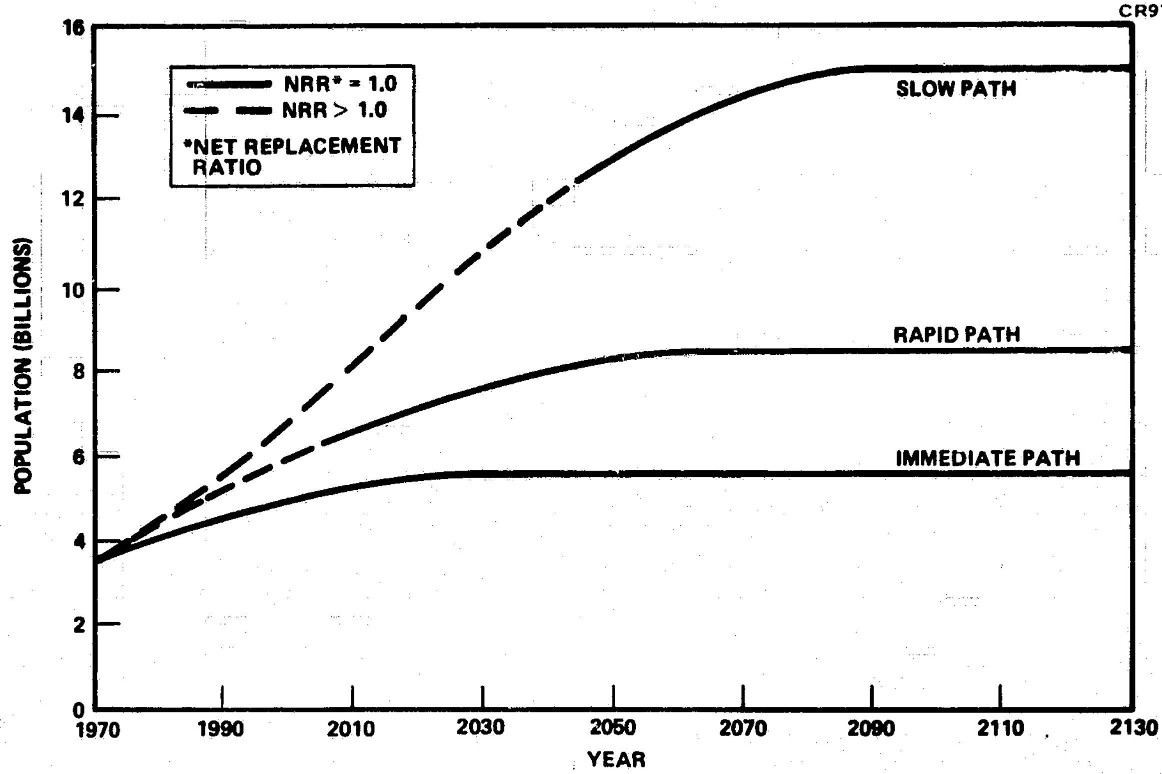

SOURCE: TOMAS FREJKA, THE FUTURE OF POPULATION GROWTH: ALTERNATIVE PATHS TO EQUILIBRIUM, 1973

Figure A-1. Growth Potential of the World Population

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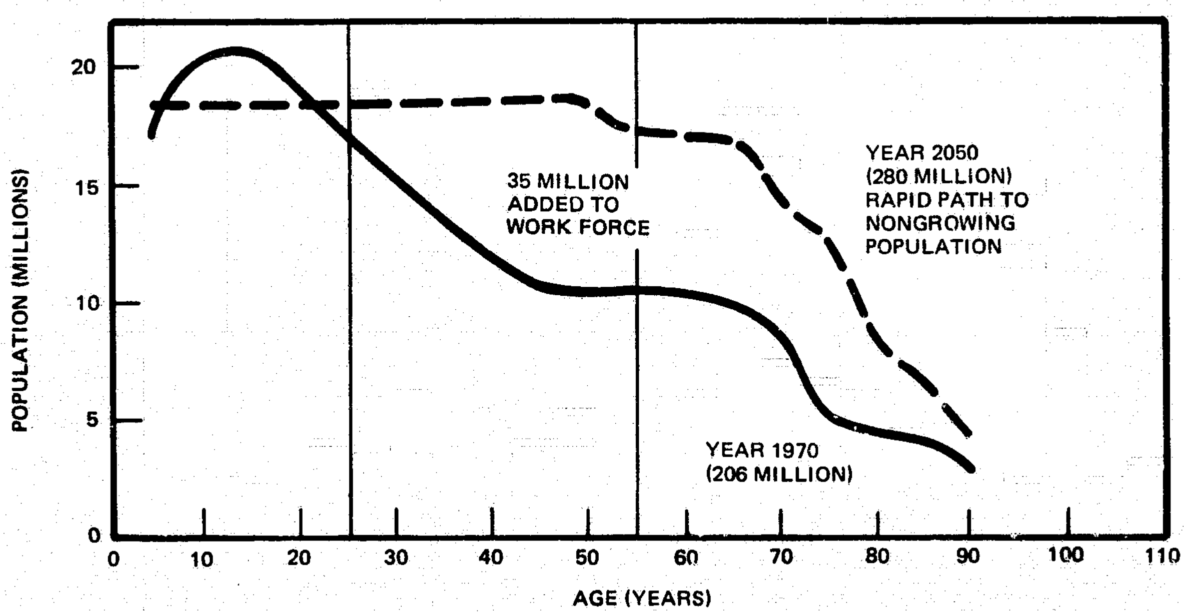
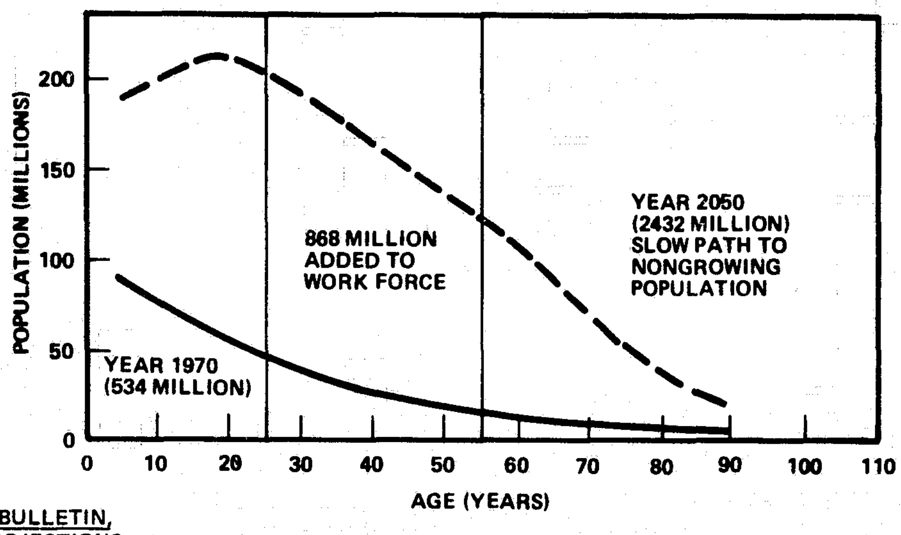


Figure A-2. Population Projection-USA



SOURCE: POPULATION BULLETIN, WORLD POPULATION PROJECTIONS: ALTERNATE PATHS TO ZERO GROWTH, VOL.29 NO. 5, POPULATION REFERENCE BUREAU, INC., WASHINGTON, D.C., 1974

Figure A-3. Population Projection-India

effective work force age groups (25 to 55 years of age). For the Indian population projection, the increase equates to almost a five-fold increase in work force between now and the year 2050. This statistic suggests that, in these two countries alone, nearly one billion additional people will need to be educated to a level sufficient for them to cope with both the rising standard of living and advancing technological progress of their nation. The requirement for this educational increase will place a tremendous burden on the schools and education institutions of India, perhaps requiring radical and involvative approaches to reach the masses of people involved. Educational services can represent a major potential market opportunity. One way the MOF payloads might service this need is in the area of space-ground communications systems. Systems can be envisioned where the large and high power elements of the network could be placed in space where unlimited access to solar power as an energy source is available. Direct to-the-home communications links (two-way circuits) could be established at significantly reduced per capita costs when compared to conventional land-line or ground point-to-point transmissions. Cost reductions would be realized by eliminating the

need for many ground transmitters and terminals and by providing for the high-power portion of the system to be located in space so that the receivers and transmitters on the ground could be relatively inexpensive mass-produced low-power devices. MOF could serve to establish and maintain facilities for the assembly and servicing of very large scale antennas and solar collectors in space. These systems could be tied in with other Earth observations space platforms and payloads to provide education, farm information, weather forecasts, health services, and food conditions at very modest per capita investments.

Another problem of serious concern to "futures" researchers is world food production and distribution. Agronomy has advanced to the point where the production of crops, assuming the proper availability and application of technology, can meet the needs of the growing population <u>in total</u>. The problem lies in the distribution on the local, regional, national, continental and platetary scales to get the products of the land to needy peoples on a timely basis. With growing demand the futurists see <u>all</u> food and farm products, assuming an emerging adequate transportation system, to have economic value. These trends would suggest to Mr. Enzer an active role for MOF to support Earth observations activities on a global scale coupled with adequate communications measures to get the right information to the right individual at the right time and place.

- Mr. IVAN BEKEY, Advanced Orbital Systems Division, Aerospace Corporation

Mr. Bekey is the study director of the "Commonality of Space Vehicle Application to Future National Needs" study, Contract NAWw-2727 and was contacted as a suggested source of new user requirements for MOF. He was briefed on the general characteristics and the payload support services available from MOF and in turn provided to the study team the current results of the aerospace study as a possible source list for MOF utilization potential.

- Dr. PHILOMENA GRODSKA, Staff Scientist, Lockheed Missiles and Space Division

  Dr. Grodska is the chairman of the AIAA Technical Committee on Space Processing. She agreed to approach her committee, through a special subcommittee, to assess the new user potential for space processing of MOF. Members of the subcommittee in addition to Dr. Grodska, include Dr. W. H. Steurer of General Dynamics/Convair Division, and Dr. R. T. Frost of General Electric Company. A fourth member is Mr. Grant H. Barlow of Abbott Laboratories to provide the needs of biological and pharmaceutical materials production in space.

  Dr. Grodska reports that the interest is very keen in the scientific and engineering communities in this area of applied research using space based facilities. The results of Skylab and other experiments have been very promising and, while there is not currently a clear-cut path to immediate commercial uses of space for materials processing, further extensions of this work utilizing the MOF capabilities is most desirable.

- Mr. R. J. GUNKEL, NASA Research and Technology Advisory Council

  Mr. Gunkel, as Chairman of the NASA Research and Technology Advisory Council Panel on Space Vehicles, was contacted at NASA's suggestion as a source of information regarding individuals in industrial and academic organizations who should be interviewed as representatives of the users of future manned orbital facilities. A number of individuals were identified by Mr. Gunkel as potential sources of useful MOF utilization commentary.

- Mr. GILBERT OUSLEY, NASA Senior Scientific Representative in Australia

  Mr. Ousley of the NASA-Goddard Spaceflight Center sees the space program remaining at its present funding level and becoming much more applications oriented. For example, Earth problems such as Earth resource discovery, food production monitoring and urban growth could well be satisfied with the combination of satellite/MOF supplied information. He views the future with increased multi-national cooperation.

His review of the MOF design drew the following comments. The modular construction utilizing duplicated elements are a desirable feature. The small crew size enhances the MOF system approach by minimizing onboard requirements for "usables." The modular approach making individual units available is also attractive to independent companies and countries on a sole use or proprietary basis.

Long-term, high payoff areas, as forecasted by Mr. Ousley, include manufacturing in space, medical utilization (hospitals in space), satellite repair facilities and the development of new agricultural seed strains.

The timeframe, crew size and facility usage for MOF evolution are as follows:

- 1985 - 4-to-6 man crew, 100 day missions, research
- 1990 - 20-man crew, 6 month missions, development and manufacturing
- 1995 - 100-man crew, one year missions
- 2000 - 1,000 inhabitants, continuous mission, manufacturing plant, hospital, research institutions

- Mr. RICHARD D. JOHNSON, NASA Ames Coordinator, Space Colonization Summer Study, and various study group members

The purpose of the Summer Study was to examine the feasibility of setting up human communities in space. Twenty-eight faculty, students, and volunteer visitors from colleges, universities and industry made up the study group. During the Summer Study the group described a system for colonizing space and found no fundamental scientific obstacles to such an undertaking. Key members of the Summer Study Team were contacted to discuss the implications and/or critical issues or questions which were identified in their study which in turn should be addressed and answered prior to the initiation of such a major program.

Specifically, it was desired to identify issues which could be profitably addressed by a manned orbital facility such as that developed in the MOSC Study. Conversations were held with Charles Holbrow of Colgate University,

Ralph Sklarew of Xonics, Thomas Heppenheimer of California Institute of Technology, Allan Russel of Hobart and Wm. Smith Colleges, and David Voltmer of Pennsylvania State University. The design questions which the group believed needed to be addressed prior to the development of a large space colony revolved primarily around the long term effects of the space environment on living organisms. Examples of the types of questions which the participants felt needed to be answered before a colony could be designed are the following: What are the important factors in stimulating the growth of plants and animals in space? What are the long term effects of zero g or reduced g on multiple generations of living organisms? Is one g environment necessary? What are the critical environmental factors in atmospheric compositions? Are trace gasses needed in long term (multi-generation) development? What are the optimal synergistic relationships of all environmental factors (i.e., radiation levels, g levels, atmospheric constituents, etc.) for survival and growth? It was suggested that these types of questions should be included in the mission planning for the early extended duration manned space facilities.

- Mr. ATHELSTAN SPILHAUS, Consultant and Author

Mr. Spilhaus states that the US faces increasing competition in the world marketplace and must maintain its technological lead over other nations by exploiting the utilization of space. The modular MOF approach establishes the required versatility to develop many diverse uses without having to plan the future in every detail. He sees high economic payoffs for zero gravity and high vacuum technology but return on investment as such, is not a good measure of really advanced ideas. Spilhaus also suggests that medical implications for developing new techniques or procedures should not be overlooked.

- Dr. PETER E. GLASER, Vice President, Arthur D. Little, Inc.

Dr. Glaser commented that "MOF represents an interesting solution and sooner or later will be required. . . (but) needs to be tied to specific end objectives," even in the initial missions. He views the industrialization of

space to be an exciting prospect, and visualizes satellite solar power stations as offering great potential for opening up or stimulating the industrialization process.

- Commander JOSEPH P. KERWIN, M. D., USN; Lt. Col. WILLIAM R. POGUE, USAF; Commander PAUL J. WEITZ, USN; Astronauts Office, Johnson Space Center

In a meeting with Astronauts Pogue, Weitz, and Kerwin, a number of significant points drawn from their Skylab experience and bearing upon the design and utilization of manned orbital facilities were made. Comments recorded are as follows. ". . . As many windows as possible should be incorporated in the baseline facility design. It is very important considering the reliability of eyeball visibility to be able to view all the vehicle through a direct optical path. A hemispheric viewing position protruding out the outer skin of the vehicle would be desirable and the use of a perioscope to extend viewing capability should also be considered."

". . . A full-time vehicle/crew commander is absolutely necessary. This would minimize the interruption of individual crew scientists during delicate research activities for response to vehicle support or subsystem requirements. This reduces individual pressures and "takes the heat off" payload specialists so that their primary tasks can be conducted with maximum effectiveness. For complicated payloads, one to two years of training are necessary."

". . . Eight hours of crew work activity on a routine basis is the upper limit of man's capacity in space operations. If two-shift operations are necessary they should be spread over 12-14 hours permitting all the crew to sleep at the same time."

". . . Isolation and sound proofing of sleeping quarters is very important. Sleeping quarters should be remote from other activity areas including the wardroom and personal hygiene compartment."

". . . The perceptual phase-amplitude-frequency relationships of noises should be considered. For example, on Skylab the noise from the No. 1 hydraulic pump was pulsing or "beating" and although the db levels were acceptable, the variation in frequency was extremely annoying."

". . . It is desirable to have two crewmen supporting each other for EVA as well as one crewman inside acting as a monitor in the event that a hazard such as becoming entangled in some portion of the external structure occurs; however, for operational EVA it possibly would not require a full-time support crewman. An alternative could be the assignment of one crewman within the station as having primary responsibility for periodic visual monitoring but with a full-time audio communications hookup."

". . . It is preferred that batteries be located externally for EVA replacement and servicing. Batteries will be a definite hazard and would cause concern to the crew if located within the pressurized area. Palletizing for convenient handling by EVA was recommended."

". . . Location of the logistics module is unimportant with regard to the utilization area, however, it is important that consumables be packaged for ready use and not require rearranging, restocking of shelves, etc., at the point of utilization."

". . . Mission planning should allow two to five days overlay for crew changeover at logistics periods for adequate briefing/debriefing of vehicle status, etc."

Lt. Col. Pogue specifically felt that the features desirable for an Earth observations manned facility should include the following:

A. Unrestricted viewing (direct optical path from eyeball to object) of dark and daylight Earth. Dark Earth eyeball viewing is considered a most important area, the potential of which is yet to be explored.

B. Central operator viewing facility with the following features:

1. Manual pointing of telescopes and instruments.
2. Surface feature automatic tracking.
3. Moving map display depicting area in field of view in same perspective as visual field from vehicle.
4. Zoom optics with good focus and wide eye relief.
5. Alphanumeric display in field of view showing instrument parameters and time.
6. Time tagging of verbal comments and data.
7. Film or video record of activity viewing sequences.

C. Imaging instruments to record data and provide real time image repeater (monitor of what the instrument is getting).

D. Variable or operator selected color coding for image feed to display monitor for multi-instrument, multi-spectral instrument combinations.

E. Selective image combinations.

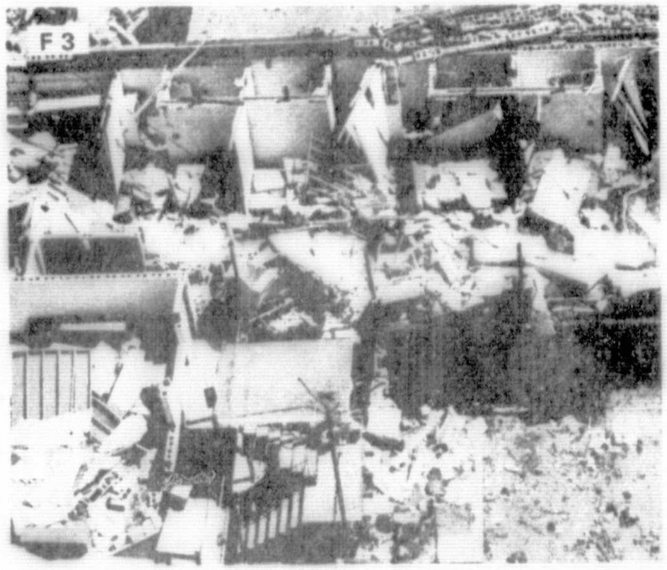
- Professor T. THEODORE FUJITA, Dept. of Meteorology, University of Chicago

Dr. Fujita, who is often called "Mr. Tornado," is probably the world's most eminent authority on tornadoes. This subject has occupied his lifelong work both in the USA and Japan. He has published many books, technical papers, and articles on tornadoes, their characteristics and the devastation that they have dealt to human life and property. He has devised a six-point scale, the Fujita F-scale, to classify the destructive force of tornadoes (F0 - light damage, F1 - moderate damage, F2 - considerable damage, F3 - severe damage, F4 - devastating damage, F5 - incredible damage [Figure A-4]). At F5 winds are encountered of over 300 mph (Mach 0. 5).

Dr. Fujita diagrammed a phenomenally large scale "superoutbreak" of tornadoes experienced over a wide area of the United States ranging from Alabama on the south to Indiana on the north beginning April 3, 1974 and lasting to the morning of the next day. The significance of this jumbo tornado outbreak can be appreciated in the statistics which reported from 13 states a total of 148 tornadoes within a 16-hour period, dealing death to 315 individuals,

Scale	m / sec	Knots	mph	Expected Damage
F 0	17.8- 32.6	35- 63	40- 72	LIGHT DAMAGE
F 1	32.7- 50.3	64- 97	73-112	MODERATE DAMAGE
F 2	50.4- 70.3	98-136	113-157	CONSIDERABLE DAMAGE
F 3	70.4- 91.9	137-179	158-206	SEVERE DAMAGE
F 4	92.0-116.6	180-226	207-260	DEVASTATING DAMAGE
F 5	116.7-142.5	227-276	261-318	INCREDIBLE DAMAGE

From SMRP Research Paper Number 91.



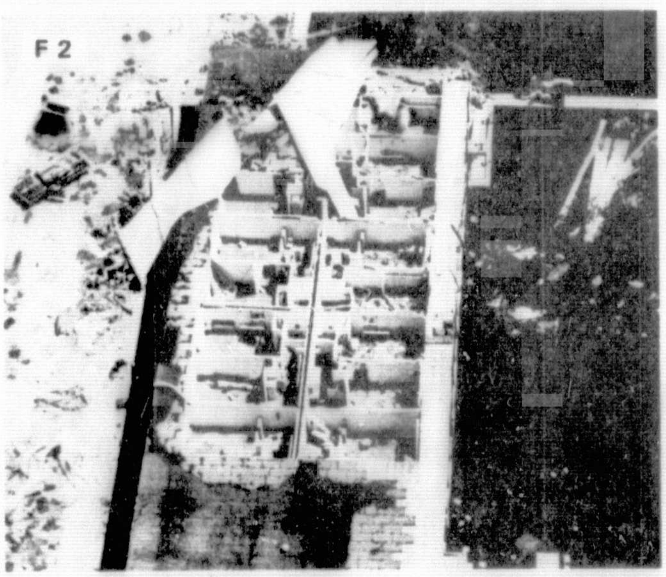


Figure A-4. Damaging Wind Scale by Fujita

injuring another 5484 and causing property destruction estimated in the billions of dollars. Dr. Fujita points out that tornadoes offer little prior warning of their occurrence and, unlike other destructively severe storms such as hurricanes which can be tracked for days before reaching populated areas, tornadoes are characterized by rapid onset and heretofore unpredictable destruction paths.

Dr. Fujita's study of tornadoes is aimed at not only understanding the basic atmospheric mechanisms which produce these storms, but also is attempting to identify indicative phenomena which can be measured and/or observed to predict their occurrence. His work has clearly shown that many meteorological parameters need to be observed on a nearly continuous basis. He has demonstrated with aerial photography the importance of proper viewing geometries and illumination angles in order to discriminate features of interest.

Dr. Fujita believes that a manned orbital facility placed in geostationary orbit, properly outfitted with remote sensors, diffraction limited-multispectral optical instruments, and most importantly having a trained human observer onboard, would be of incalculable value in understanding, predicting, and ultimately controlling the phenomena. Dr. Fujita points out that discoveries can come from human observers in many ways and man would be most useful in observing the formation and interrelationship of hail, heavy rain and tornadoes where time and space information at the proper scales needs to be "integrated" by the human intellect. Once the basic phenomena are understood and predictors developed, it may be possible for automated satellites to be established to serve as warning outposts for severe storms hazardous to mankind.

For research purposes, Dr. Fujita believes that a 90-day manned orbital flight duration would best be spread over the months of March, April and May (the principal tornado season for the North American continent). If early warning mechanisms could be developed, the great personal loss and suffering presently being experienced by thousands of persons each year in this country can be significantly reduced. The savings in life and property alone during one outbreak such as the April 1974 event could more than offset the expense of equipping and staffing the MOF with the required payloads and crew.

- Dr. EDWARD KRUSZEWSKI, Langley Research Center

Dr. Kruszewski, speaking as a representative of the NASA Solar Energy Advisary Panel believes that one of the prime uses of future space platforms will be in solar energy collection and transmission. The advantage of a MOF is seen as providing a platform for the structural assembly, maintenance and repair of solar collectors/transmitters. Costly redundant systems can be eliminated by facilities for on orbit repair.

- Mr. WILLIAM R. MARX, McDonnell Douglas Astronautics Company, St. Louis

Mr. Marx is the study manager of the Feasibility Study of Commercial Space Manufacturing, contract NAS8-31353. The purpose of this study is to examine the feasibility of and provide an engineering description of a process to produce in space single-crystal silicon ribbon in a containerless manner. Semiconductor silicon in this form offers significant economic advantage, for example, over conventional slabs cut from boules pulled from crucibles by the Czochralski method. His study is looking at an approach using an automated spacecraft for the carrier of the production facility. This choice was dictated by the following considerations. If the Space Shuttle were launched every two weeks and carried the necessary processing equipment each time, there would be a maximum of 26 missions each year. The effective operating time for these 26 missions would be 130 days according to estimates developed in the study. This type of operation is clearly less effective than an automated, free-flying manufacturing facility operating continuously for 360 days each year.

MOF could offer the same Shuttle independency advantage of the automated satellite approach. In addition, however, the presence of man could simplify the automatic apparatus required and result perhaps in a higher quality controlled product.

• Dr. W. H. STEURER, (AIAA Technical Committee on Space Processing)
Engineering Staff Specialist, General Dynamics — Convair Division

As viewed by Dr. Steurer space processing payloads, as they can be expected to evolve through the 1980 to the 1990's and beyond, can be expected to fall into two categoric approaches. The first approach would involve a large number of small, single purpose facilities with little growth or modification potential. The second approach would involve very few facilities with considerable inventories of attachments for modification and suitable for configuring to a wide variety of space processing activities. The first approach most probably is destined for Spacelab and/or automated payload flights. The second approach would be most appropriate for MOF.

The AIAA select subcommittee (as stated by Dr. Steurer) also believes that eventually space processing payloads most probably will provide greater growth potential than other payload areas. By 1990 some pilot plant production operation can be expected to be ongoing. Separate and privately owned payload modules might be common place by this time frame.

2. MSFC Contacts

In addition to the Industrial, Commercial and Institutional contacts made directly by the MDAC study team, MSFC contacted agency sources such as the Space Shuttle Payload Planning Working Groups. Some of the comments advanced by personnel contacted directly by MSFC were as follows:

• Dr. JAMES H. BREDT, Code ES, Space Manufacturing

An Automated free-flyer for the commercial space processing of silicon ribbon appears desirable. NASA should investigate feasibility/cost effectiveness of processing in a MOF. Low cost is key in commercial space processing. MOF can be used to "warehouse" space processing equipment.

- Dr. RUFUS R. HESSBERG, Code MM, Life Sciences

The Life Sciences Working Group did a thorough job to define requirements for MOSC Study. Life Sciences requirements may require a special lab. More onboard analysis of data would be desired by the Life Scientists. More in-depth studies are needed in FY 76 space station studies.

- Mr. W. RAY HOOK/Mr. EDWARD A. GABRIS, Code RS, Advanced Technology

Technology users support Spacelab because of close association with hardware. No long duration technology program has been formulated yet. The ATL concept could support an alternate host vehicle (as compared to the Shuttle) if MOF provided a better environment/flexible schedule.

- Dr. GERALD W. SHARP, Code SG, Space Sciences

Recommend working through the MSFC member of the working groups in defining payload programs for MOF. Recommend against approaching scientific community (associated with working groups). Suggest that a seminar be scheduled in the future where invited scientists are introduced to potential capabilities of MOF and asked to consider uses. Suggest that an executive summary briefing on MOF be given to the payloads planning steering group.

- Dr. DUDLEY G. McCONNELL, Code EB, Applications

Sensor technology development is an important potential MOF program. A scheduled planning retreat for meteorology (March 1975) may provide MOF payloads. The 1974 Summer Study results and the Outlook for Space Committee results should be factored into the planning activities.

Additionally, suggestions for AMPS experiments conducted at geosynchronous orbit, remarks on the value of scientific missions for a geosynchronous space station and comments relative to the need for a manned geosynchronous station were received from Messrs. Stuhlinger, Lundquist, and Chappel of MSFC respectively.

• Dr. ERNST STUHLINGER, DS30, MSFC

In the following some activities in geosynchronous orbit are listed which could profit from the presence of man . . .

1. <u>Observations</u>
   Studies of magnetosphere, plasma environment, solar wind. Global weather observations, storm developments. Monitoring of areas which are rarely free from cloud cover (Amazon basin).

The advantage of human observers over remotely controlled instruments for these observations should be determined before a positive statement can be made.

2. <u>Operations</u>
   Experimental development and test of communication systems, earth observation systems, power relay systems, power generation systems, earth illumination systems (?). Again, the utility of man for these functions in geosynchronous orbit should be established.

3. <u>Servicing</u>
   Maintenance, modification, and repair of geosynchronous satellites by orbiting servicemen.

Cost effectiveness of the servicing mode as compared to the simple replacement of a faulty satellite by a new one must be established.

4. <u>Retrieval</u>
   Rendezvous, capture, and retrieval operations will profit from the presence of astronauts onboard the retrieval spacecraft.

5. <u>Way Station</u>
   Assembly station for planetary and deep spacecraft. Parking area for outgoing and returning craft. Quarantine station under astronaut supervision.

Assembly station for power relay satellites, solar power satellites, large communications and observations satellites.

- Dr. CHARLES A. LUNDQUIST, ES01, MSFC

From an economic point of view, before an experiment is considered for a geosynchronous space station, some significant advantage should exist from doing the experiment in geosynchronous orbit rather than on a spacecraft nearer to the earth. One class of experiments meeting this criterion are an outgrowth of the atmosphere, magnetosphere and plasmas in space (AMPS) experiments planned for earlier execution on near earth spacelab missions.

Another class of experiments making particular use of the geosynchronous altitude are those astronomical measurements that benefit from a very long baseline between observation sites.

- Dr. CHARLES R. CHAPPELL, ES23, MSFC

The geosynchronous orbit space station mission would be ideally suited for an AMPS complement of instrumentation. . . The ability to conduct experiments with time durations of minutes up to several hours are ideally suited for the astronaut participation, and the ability to react to the perturbations which are generated by the space station uses the scientist involvement to the fullest.

C. 2